BRUSH

OPERATING INSTRUCTIONS

amplifier

model RD 5612 00

MP MASTER

MA30149

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■ Claim for damage in shipment

The instrument should be examined as soon as it is received. If it is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained from the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number, type number and serial number when referring to this instrument for any reason.

■ If any fault develops

1. Notify the nearest factory branch service station, address on the next page, giving full details of the difficulty, and include the model number, type number and serial number. Upon receipt of this information, we will give you service instructions or issue a material return authorization card.
2. You may request any necessary instrument packaging by telling us what cartons you need. These will be sent to you no charge.
3. Upon receipt of shipping instructions, forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins, provided the instrument is not covered by the warranty.

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WARRANTY

Each instrument manufactured by Brush Instruments, Division of Clevite Corporation, is warranted to be free from defects in material and workmanship and to operate in accordance with the published specifications when used with the recommended Brush associate equipment and with Brush chart paper. Liability under this warranty is limited to servicing or adjusting any instrument returned to a factory branch service station for that purpose and to replacing any defective parts thereof except tubes, fuses, and batteries.

This warranty is effective for one year after delivery to the original purchaser. When the instrument is returned transportation charges are to be prepaid by the original purchaser. If defective operation has been caused by misuse or abnormal conditions of operation, repairs will be billed at our current rate. In this case an estimate will be submitted before work is started.

SUPPLIES AND SERVICE

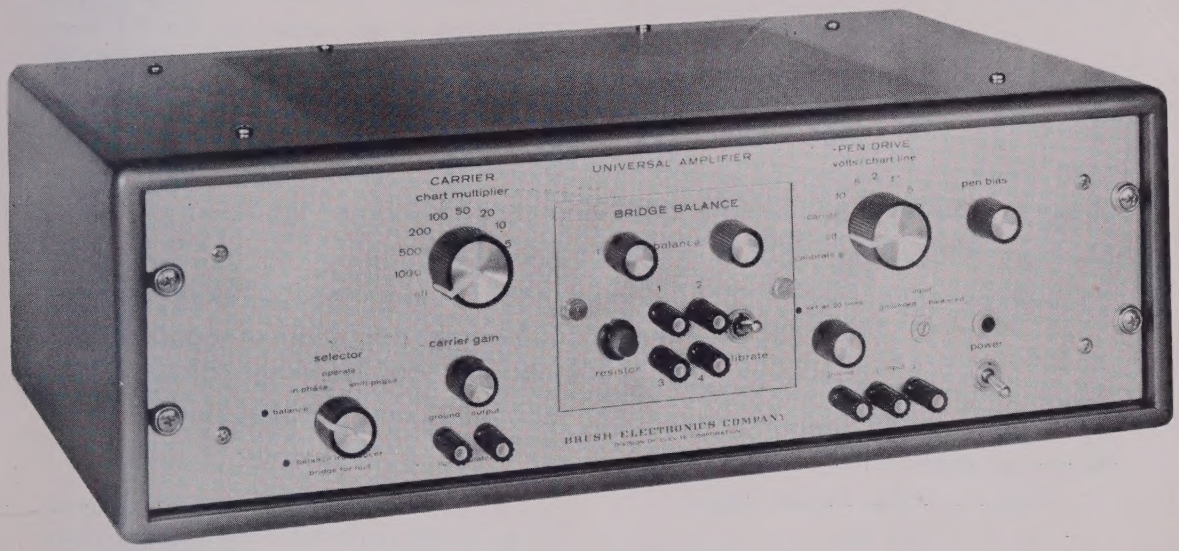
Brush Instruments factory branch offices and service stations:

CLEVELAND
Mid-West
3405 Perkins Avenue
Cleveland 14, Ohio
Phone: ENdicott 1-3315

ARLINGTON
East Coast
561 - 23rd St., South
Arlington 2, Virginia
Phone: OTis 4-5912

LOS ANGELES
West Coast
1960 So. La Cienega Blvd.
Los Angeles 34, California
Phone: TExas 0-7517

UNIVERSAL AMPLIFIER MODEL RD 5612 00



Universal Amplifier Model RD 5612 00 with Bridge Balance Model RA 5212 00 in Portable Case Model RA 1105 30.

The Universal Amplifier Model RD 5612 00 is both a high gain carrier amplifier and a medium gain d.c. amplifier. The unit is designed primarily for operation with resistive and reactive transducers, and may be ordered with the Bridge Balance Model RA 5212 00 or the LVDT Balance Model RA 5222 00. A balance box is essential to the operation of the carrier section of the amplifier, while the d.c. section is complete in itself.

As a carrier amplifier with the Bridge Balance Model RA 5212 00, the Universal Amplifier can be used with strain gages and variable reluctance transducers, with resistance values from 50 to 5000 ohms.

As a carrier amplifier with the LVDT Balance Model RA 5222 00, the Universal Amplifier can be used with linear variable differential transformers or other inductive transducers.

Balance boxes for use with specific variable reluctance transducers may be obtained on special order from Brush Instruments, Division of Clevite Corporation.

As a d.c. amplifier the unit is capable, at maximum sensitivity, of deflecting a Brush oscillograph pen 1 mm with an amplifier input signal of 50 millivolts. With proper adjustment, the unit may be used with an oscilloscope or similar equipment. In such operation, the amplifier has a response down no more than 3 db at 5000 cps.

The Universal Amplifier Model RD 5612 00 is designed for use with oscillographs of the Brush "RD" series. The unit may be used with earlier Brush oscillographs if the frequency response of the amplifier is adjusted for use with the penmotors in such oscillographs, as described under "Frequency Compensation of the D.C. Amplifier Section."

SPECIFICATIONS

AS A CARRIER AMPLIFIER

Frequency response	The recording of a constant voltage sine wave modulation of the carrier will be ±1 chart line (mm) of a nominal 10 chart lines (mm) peak to peak, from d.c. to 100 cps when the amplifier is compensated with a Brush oscillograph.
Sensitivity with Brush oscillograph	1 microvolt per chart line (mm).
Maximum voltage gain	1,500,000.
Bridge exciter frequency	2000 cps ±5%. Provision is made to synchronize oscillators of two or more Brush Universal Amplifiers for multiple operation.
Bridge exciter voltage	Maximum 3 volts (120 ohm load).
Measuring range	
Using the Bridge Balance Model RA 5212 00	1.0 to 40,000 microinches per inch per chart line (mm) with one active 50 to 5000 ohm gage (gage factor 1.7 or higher).
Using the LVDT Balance Model RA 5222 00	Determined by type and sensitivity of transducer used. The output of the transducer must be at least 1 microvolt with an input of 50 millivolts at 2000 cps.
Chart multiplier steps	1, 2, 5, 10, 20, 50, 100, 200, 500, and 1000.
Demodulator output	For observation of demodulated signal up to 200 cps (down 2 db at 200 cps).
Noise	Less than ¼ chart line (mm) peak to peak during operation.

AS A MEDIUM GAIN D.C. AMPLIFIER

Frequency response	The recording of a constant voltage sine wave will be ±1 chart line (mm) of a nominal 10 chart lines (mm) peak to peak from d.c. to 100 cps when the amplifier is compensated with a Brush oscillograph. Response ±½db to 1 kc, down no more than 3 db at 5 kc, for use of the d.c. amplifier section with oscilloscopes or for similar applications is obtained by switching off the compensation.

Sensitivity with Brush oscillograph	50 millivolts per chart line (mm). Full scale deflection from chart center ±1 volt.
Voltage gain	Approximately 30.
Measurement range with Brush oscillograph	
Single ended input	0.050 volt to 400 volts.
Balanced input	0.050 volt to 400 volts, side to side. Allowable voltage off ground is 1000 times VOLTS/CHART LINE switch setting (in volts) up to 500 volts off ground.
Amplifier zero line stability	¼ chart line (mm) per hour, when used with a Brush oscillograph and Brush chart paper. (Not affected by power line fluctuations between 105 and 125 volts or between 95 and 115 volts). Total drift over eight hour period not more than ½ chart line (mm).
Input impedance	
Single-ended	5 megohms.
Balanced	10 megohms.
Sensitivity steps	.05, .1, .2, .5, 1, 2, 5, and 10 volts per chart line (mm). Maximum attenuator error 1% with balanced input.
Calibration	Signal derived from internal mercury cell.
Signal expander	A pen positioning control (PEN BIAS) is provided. This control permits balancing out the static component of a complex signal, deflecting the signal zero line as much as 200 lines (ten times full scale deflection) either side of chart center, except when balanced input is used.

GENERAL

Output impedance	Approximately 50 ohms.
Maximum output current	±20 milliamperes into 1500 ohms.
Input power required	105 to 125 volts (or 95 to 115 volts), 50 to 2000 cps, 90 watts (nominal).
Fuse	2 amp, 250 volts, type 3 AG.

Tubes	
Carrier amplifier	1-12AU7, 1-12AX7, 1-12AT7, and 1-6AL5.
D.C. amplifier	1-12AX7, 2-12AT7WA, and 2-5687.
Power supply	1-OA2, 1-6BW4, 1-6080, and 1-5751.
Input terminals	
Front	Binding posts.
Rear	d.c.: 3 pin male AN type (matching connector supplied). bridge: 5 pin female AN type (matching connector supplied). sync: 2 pin male AN type (matching connector supplied).
Output terminals	6 pin female AN type (cables to connect amplifier to Brush "RD" series oscillographs supplied).
Dimensions	
Universal Amplifier	Standard panel: 19″ wide x 5¼″ high x ¼″ thick. Depth: 10¾″ (with connectors, 12½″).
Bridge Balance	Panel: 4½″ wide x 3½″ high x ⅛″ thick. Depth: 2¼″.
LVDT Balance	Panel: 4½″ wide x 3½″ high x ⅛″ thick. Depth: 2¼″.
Net weights	
Universal Amplifier (less balance box)	22 lbs.
Bridge Balance	1 lb., 2 oz.
LVDT Balance	1 lb., 2 oz.
Shipping weights	
Universal Amplifier (less balance box)	28 lbs.
Bridge Balance	2 lbs.
LVDT Balance	2 lbs.

REMOVING INSTRUMENT FROM CARTON

Remove the amplifier and all accessory items from the carton. See that all items in the packing list (below) are included in the shipment. Examine the instrument and accessory items for damage. For procedure to be followed if damage is noted, refer to "Claim for Damage in Shipment" following the Table of Contents.

PACKING LIST

The following items are included with the Universal Amplifier Model RD 5612 00, and should be in the shipping carton at time of delivery:

1. One balance box (installed in amplifier front panel).

Either the Bridge Balance Model RA 5212 00, the LVDT Balance Model RA 5222 00, or a special balance box may be included with the Universal Amplifier, depending on which was specified at time of ordering. Check name plate on balance box to see that proper box has been included.

2. One amplifier-to-oscillograph signal cable, Part No. 223385-501 (fits all Brush "RD" series oscillographs).
3. One sync input connector (2 pin female, AN type), Part No. 119992.
4. One signal input connector (3 pin female, AN type), Part No. 121275.
5. Two cable clamps (for 2 and 3 pin connectors), Part No. 119993-104.
6. One pickup connector (5 pin male, AN type), Part No. 119973.
7. One cable clamp (for 5 pin connector), Part No. 119993-106.
8. Four fixed wire-wound resistors (120 ohms $\pm 1/4\%$, 1 watt), Part No. 3-108688-102 (included only when the Bridge Balance Model RA 5212 00 is ordered with the amplifier).

INSTALLING THE INSTRUMENT IN RACK OR PORTABLE CASE

The Universal Amplifier may be installed in a standard 19″ rack or in the Brush Portable Case Model RA 1105 30.

To install the Universal Amplifier in a standard 19″ rack, position the instrument in the rack, secure the front panel to the rack rails with four screws, and connect external cables to the front or rear of the amplifier as described below. Such a permanent installation is desirable when the amplifier is to be used with other rack mounted instruments.

In applications where maximum portability is desired, the Brush Portable Case Model RA 1105 30 is recommended. The case is 20⅛″ wide, 6⅜″ high, and 10⅜″ deep. When the amplifier and Portable Case are purchased together, the amplifier is installed in the case at the factory. Instructions for installing the amplifier are included with the Portable Case when it is purchased separately. The amplifier may be ordered with a 3 conductor power cable for portable applications.

PREPARATION FOR USE

USE WITH OSCILLOGRAPHS

The Brush Universal Amplifier is designed to be used with Brush "RD" series oscillographs. It may be used with Brush "BL" series oscillographs, but frequency response and sensitivity will differ from the values noted under "Specifications".

If the amplifier is used with Brush "BL-200" series oscillographs, circuitry of oscillographs must be inspected to see that resistance between penmotor leads and case exceeds 100 megohms.

If the amplifier is used with a Brush Model BL-206 or Model BL-208 Oscillograph, special conversion information for the oscillograph may be obtained from the Service Department, Brush Instruments, Division of Clevite Corporation, 3405 Perkins Avenue, Cleveland 14, Ohio.

If the amplifier and an oscillograph of the "RD" series are purchased together as a matched recording system, the amplifier is frequency compensated at the factory for operation with that particular oscillograph. If the amplifier and oscillograph are purchased separately, the amplifier must be frequency compensated for use with the oscillograph.

CONNECTING AMPLIFIER TO OSCILLOGRAPH

The output terminals of this amplifier are 30 volts (d.c.) above chassis, and should not be connected to any load in which either terminal is grounded. To connect the amplifier to an oscillograph, proceed as follows:

1. See that the amplifier and oscillograph are disconnected from their power source, and that power switches of the amplifier and oscillograph are in "off" position.

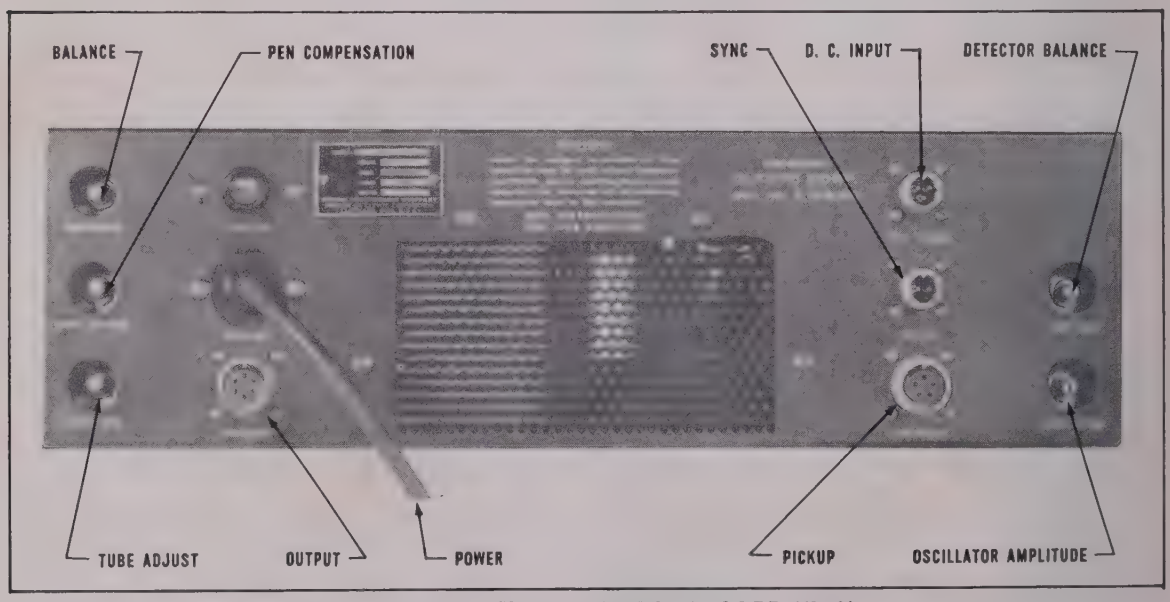


Fig. 1. Rear Panel—Universal Amplifier Model RD 5612 00.

2. Connect the amplifier OUTPUT connector (Fig. 1), on the back of the amplifier, to the oscillograph input connector with the cable supplied.

CONNECTING AMPLIFIER AND OSCILLOGRAPH TO POWER SOURCE

1. Refer to the operating instructions for the oscillograph, and connect the oscillograph to its power source. Test the oscillograph for proper operation, and turn the oscillograph power switch "off".

2. Connect the amplifier POWER cable (Fig. 1) to an appropriate power source. (The amplifier may be operated on power line frequencies from 50 to 2000 cps. Although the amplifier operates normally on power line voltage of 105 to 125 volts, the power transformer connections can be modified for operation at 95 to 115 volts. See "Modification of Power Transformer Connections for Operation at 95 to 115 Volts" in Section V—Maintenance.)

BALANCING AND FREQUENCY COMPENSATION

BALANCING THE D.C. AMPLIFIER SECTION

The d.c. amplifier section should be balanced after connection of the Universal Amplifier and the oscillograph to their power source. To balance the d.c. amplifier section, proceed as follows:

1. Turn the VOLTS/CHART LINE switch (Fig. 2) to "off". Turn the amplifier POWER switch (Fig. 2) to "on" and allow 15 minutes for the amplifier to warm up.

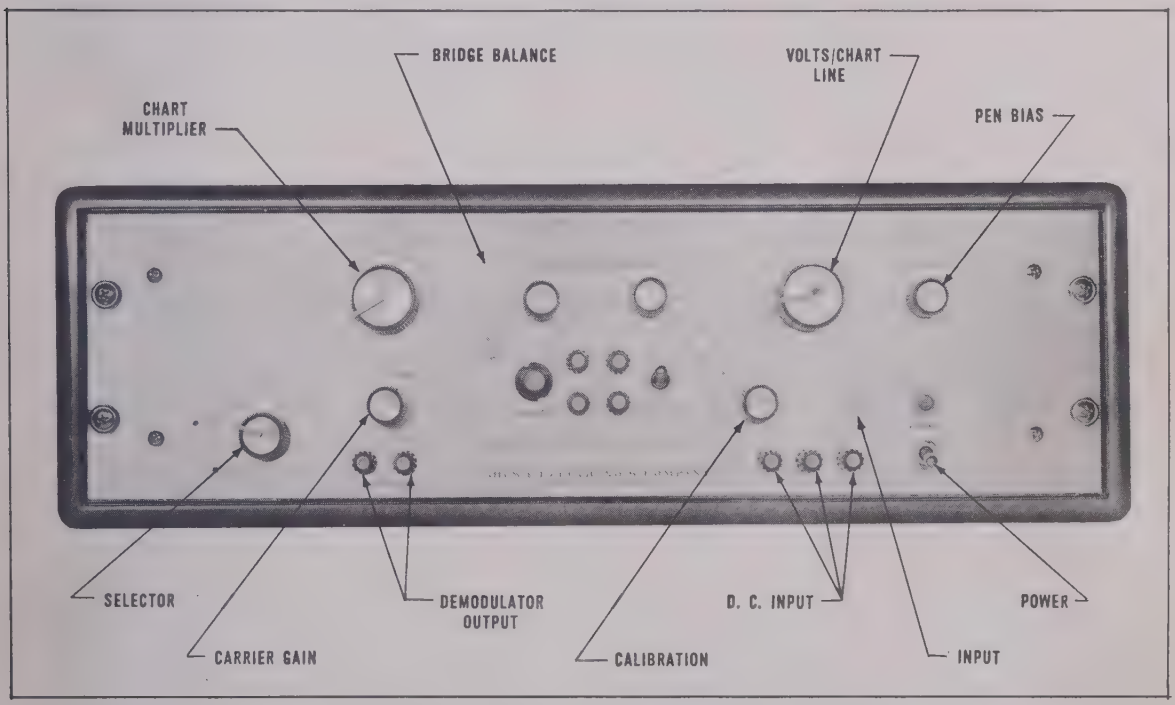


Fig. 2. Universal Amplifier Model RD 5612 00, with Bridge Balance Model RA 5212 00.

2. Turn the oscillograph "on".
3. Set the INPUT switch (Fig. 2) in the "balanced" position.
4. Turn the CALIBRATION control (Fig. 2) full clockwise, then bring the oscillograph pen approximately to chart center by means of the TUBE ADJUST control on the rear panel of the amplifier (Fig. 1).
5. Turn the BALANCE control, on the rear panel of the amplifier (Fig. 1), to its extreme counterclockwise position. Rapidly rotate the CALIBRATION control (Fig. 2), counterclockwise, then clockwise, while turning the BALANCE control slowly clockwise until no pen deflection is noted.
6. Center the pen on the chart by means of the TUBE ADJUST control on the rear panel of the amplifier (Fig. 1), and turn the oscillograph "off".

FREQUENCY COMPENSATION OF THE D.C. AMPLIFIER SECTION

To obtain optimum frequency response of a Brush amplifier-oscillograph combination, the frequency response of the d.c. amplifier section must be adjusted to match the penmotor of the oscillograph. (When an amplifier and an oscillograph are purchased as a matched system, this adjustment is made at the factory. If the instruments are purchased separately, and if frequencies over 30 cps are to be recorded, the frequency compensation procedure must be observed.) When the Universal Amplifier is used with a Brush oscillograph and optimum transient response is desired or flat response to high frequencies is not required, the PEN COMPENSATION control (Fig. 1) may be turned "off" (fully counterclockwise).

To match the d.c. amplifier section to an oscillograph, balance the d.c. amplifier section as described under "Balancing the D.C. Amplifier Section", above, and proceed as follows:

1. Connect an oscillator covering the range from 10 to 100 cps to the INPUT 1 terminal (Fig. 2) and the INPUT 2 terminal (Fig. 2) on the front of the amplifier. If the corresponding D.C. INPUT connector (Fig. 1) on the rear of the amplifier is used, connect the oscillator to pin "A" (ground) and pin "C". To reduce hum pickup, it is recommended that shielded leads be used.
2. Set the INPUT switch (Fig. 2) in the "grounded" position.

   When the INPUT switch (Fig. 2) is in the "grounded" position, the INPUT 1 terminal is shorted to ground, allowing connections to be made at the INPUT 1 and INPUT 2 terminals.
3. Turn the oscillograph "on". Set the VOLTS/CHART LINE switch (Fig. 2) in the "10" position and, with the oscillograph operating at a chart paper speed of 20 or 25 mm/sec, center the oscillograph pen trace on the chart paper by means of the PEN BIAS control (Fig. 2).
4. Set the PEN COMPENSATION control (Fig. 1) in approximately mid-position.
5. At 10 cps, adjust oscillator output level for 10 lines total pen deflection (peak-to-peak). If oscillator output is not sufficient to produce 10 lines of pen deflection, turn the VOLTS/CHART LINE switch to a more sensitive position to produce 10 lines of deflection. It may be necessary to increase or decrease the oscillator output voltage or to change the setting of the CALIBRATION control (Fig. 2) to obtain the desired 10 line deflection.

   The oscillator output voltage is a reference voltage and must be held constant during the frequency compensation procedure. The settings of the oscillator output voltage control, the VOLTS/CHART LINE switch (Fig. 2) and the CALIBRATION control (Fig. 2) must remain unchanged.
6. At 100 cps (with oscillator output voltage the same as in Step 5, above), adjust the PEN COMPENSATION control (Fig. 1) as necessary to obtain a pen deflection of 10 chart lines.
7. Sweep the frequency range from 10 cps to 100 cps (holding oscillator output voltage constant) and check for flatness of response. Adjust the PEN COMPENSATION control (Fig. 1), if necessary, to obtain optimum response from 10 cps to 100 cps. Turn the oscillograph "off".

OPERATION WITH THE BRIDGE BALANCE Model RA 5212 00

INSTALLING AND CONNECTING THE BRIDGE BALANCE

To use the Universal Amplifier with strain gages install the Bridge Balance in the amplifier, as follows:

1. Set the GAGE OHMS switch (Fig. 3) in the highest range including the resistance value of the gage being used.

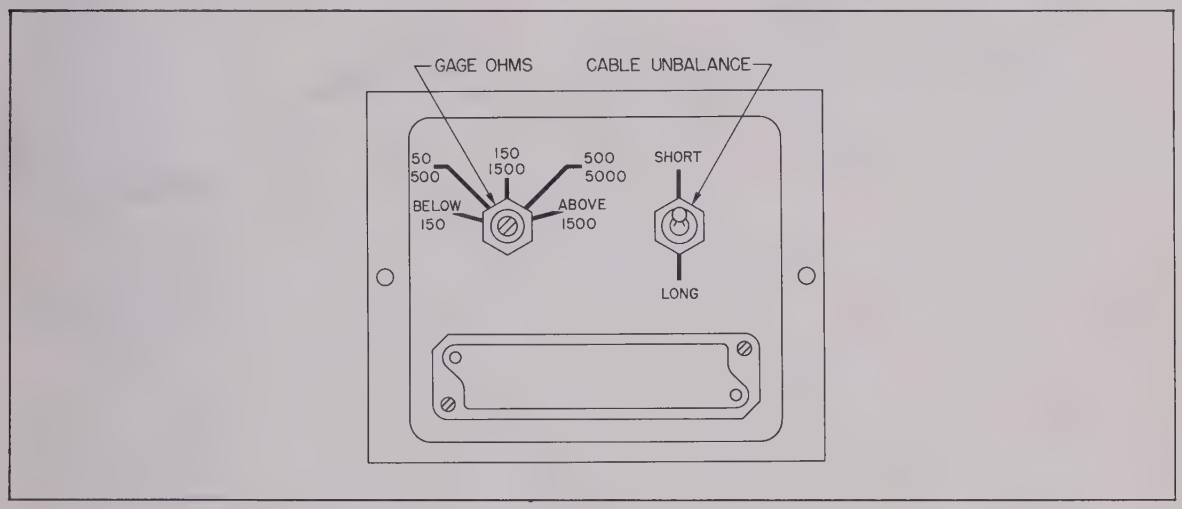


Fig. 3. Rear View—Bridge Balance Model RA 5212 00.

2. Set the CABLE UNBALANCE switch (Fig. 3) in the proper position. For most applications, the switch should be set at "short". However, if the capacitive unbalance to the strain gage bridge in the Bridge Balance is greater than that produced by 10 feet of 40 micro-microfarad per foot microphone cable, set the CABLE UNBALANCE switch in the "long" position.
3. Position the Bridge Balance (Fig. 4) in the amplifier front panel, and secure with two knurled screws.
4. Apply strain gage or gages to the material under test, following the installation instructions supplied by the manufacturer.

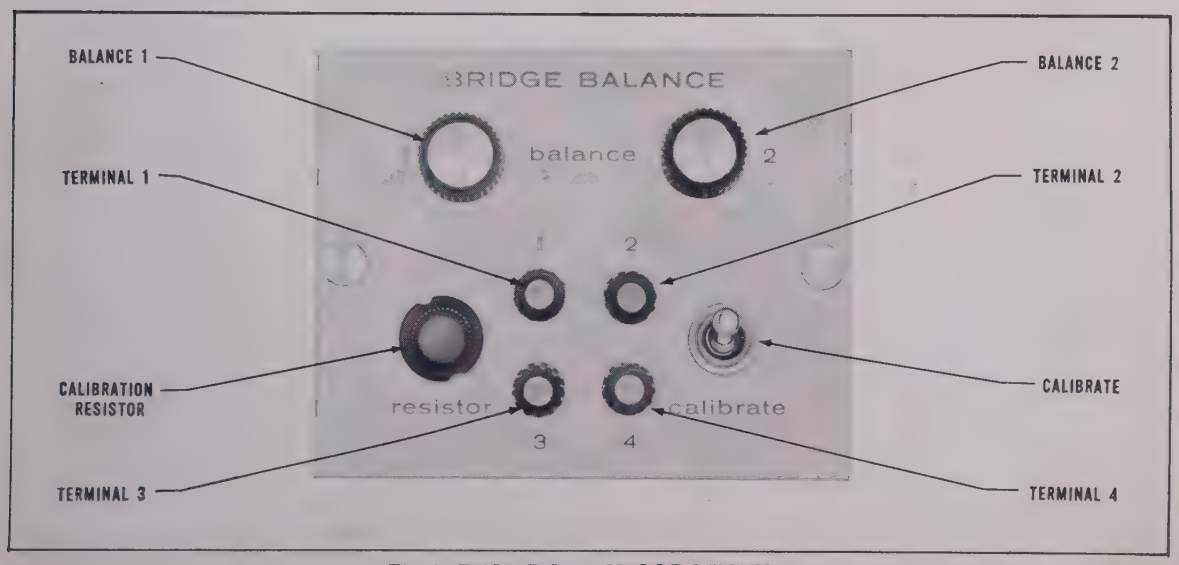


Fig. 4. Bridge Balance Model RA 5212 00.

The Universal Amplifier and the Bridge Balance may be used with many types of strain gages. Strain gage circuits may use one, two, or four active arms of the bridge circuit in the Bridge Balance. If less than four active arms are used, the bridge circuit must be completed by the installation of dummy strain gages or precision wire wound resistors, with the same resistance value ($\pm$ 1%) as the active gage or gages in use. To facilitate balancing of the bridge circuit, connect dummy gages or resistors to the Bridge Balance with shielded leads, the same length as those connected to the strain gages. Four 120 ohm, wire-wound resistors are included with the Bridge Balance for use with 120 ohm strain gages.

5. Connect the strain gage circuit (or circuits) to the bridge circuit in the Bridge Balance, as described in the following paragraphs. To facilitate comparison of tests made at different times and on different materials, follow a standard procedure in connecting and using strain gages. As a general practice, use the same length leads with all strain gages in the same bridge.

   Strain recordings may be subject to a high degree of error when strain gages are used with high resistance leads. Such error is eliminated through the use of circuits suggested by the strain gage manufacturer.

   If temperature of the material under test remains constant, or if strain measurements are taken over a short period of time, temperature compensation of the strain recording system may not be necessary. However, temperature compensation is necessary in some cases to assure accuracy in strain recordings. The following paragraphs contain more detailed information on temperature compensation in systems using one, two, or four active strain gages.

   Strain gage leads may be connected to the PICKUP connector on the rear panel of the amplifier, rather than to the terminals of the Bridge Balance (Fig. 5).

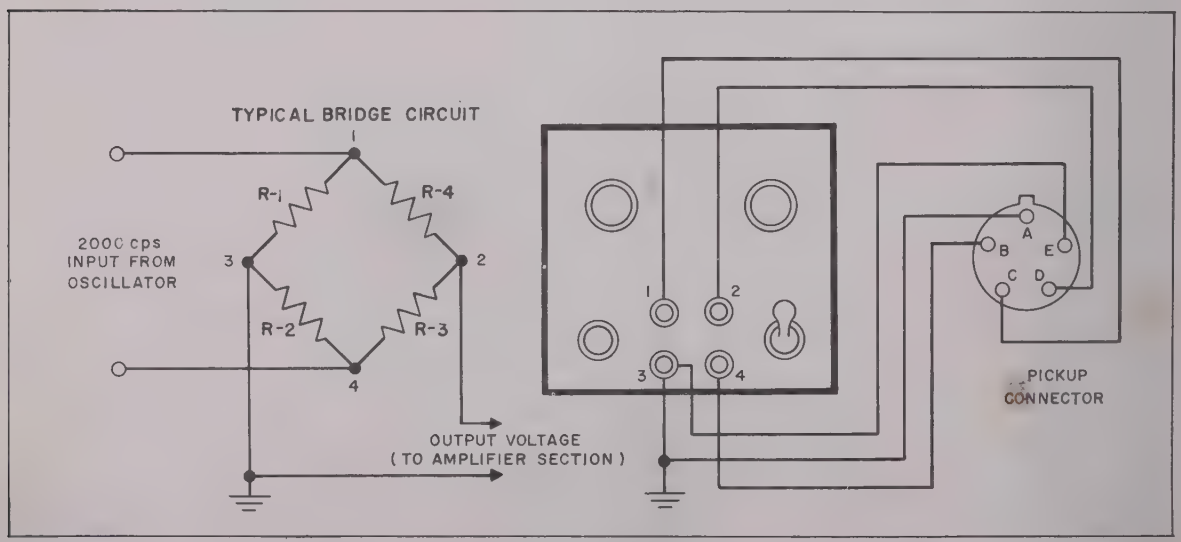


Fig. 5. Connections to the Strain Gage Bridge Circuit in the Bridge Balance.

CALCULATION OF BRIDGE OUTPUT VOLTAGE

The Bridge Balance Model RA 5612 00 is a 4 terminal bridge circuit which is used for strain measurement. A supply voltage is applied at diagonally opposite corners of the bridge, as shown in Figure 5. Output voltage from the circuit is taken from the two other diagonally opposite corners. The output voltage of the bridge circuit may be calculated as follows:

$$V_{R_2} = V\left(\frac{R_2}{R_1 + R_2}\right), \tag{1}$$

$$V_{R_3} = V\left(\frac{R_3}{R_4 + R_3}\right), \tag{2}$$

and

$$V_o = V_{R_2} - V_{R_3}, \tag{3}$$

or

$$V_o = V\left(\frac{R_2}{R_1 + R_2}\right) - V\left(\frac{R_3}{R_4 + R_3}\right), \tag{4}$$

where

V = Supply voltage,

R_1, R_2, etc. = Resistance values of resistors in the bridge circuit,

and

V_o = Bridge output voltage.

The bridge circuit is in balance and zero output voltage results when $R_1 = R_2 = R_3 = R_4$.

If a strain gage of resistance R_g (where $R_g = R_1 = R_2 = R_3 = R_4$) is connected in one arm of the bridge circuit, and if that gage is actuated, the resistance of that gage will be $R_g + \triangle R_g$. Assuming that R_2 is the active gage, then the output voltage from the bridge circuit will be proportional to resistance changes in the one active element, as shown:

$$V_o = V\left(\frac{(R_g + \triangle R_g)}{R_g + (R_g + \triangle R_g)}\right) - V\left(\frac{R_g}{R_g + R_g}\right), \tag{5}$$

so that

$$V_o = V\left(\frac{\triangle R_g}{4R_g + 2(\triangle R_g)}\right). \tag{6}$$

Since

$$2(\triangle R_g) << 4R_g,$$

then

$$V_o = V \cdot \frac{\triangle R_g}{4R_g}. \tag{7}$$

CONNECTING ONE ACTIVE STRAIN GAGE TO THE BRIDGE BALANCE

Without Temperature Compensation

The simplest method of strain measurement employs only one active arm of the strain gage circuit; expansion or contraction of the material under test due to temperature changes is disregarded. To use one strain gage without temperature compensation, connect the gage to the Bridge Balance as shown in Figure 6. Complete the inactive arms of the bridge circuit with precision wire wound resistors or unstressed gages of the same resistance value as the active gage. Under some conditions, variations in the resistance of the active gage or dummy resistors due to small variations in temperature may be large in comparison to the change in resistance of the active gage caused by strain. Since any change in resistance appears in the output of the amplifier and on the chart, the effect of small temperature variations must be checked carefully when measuring small strains.

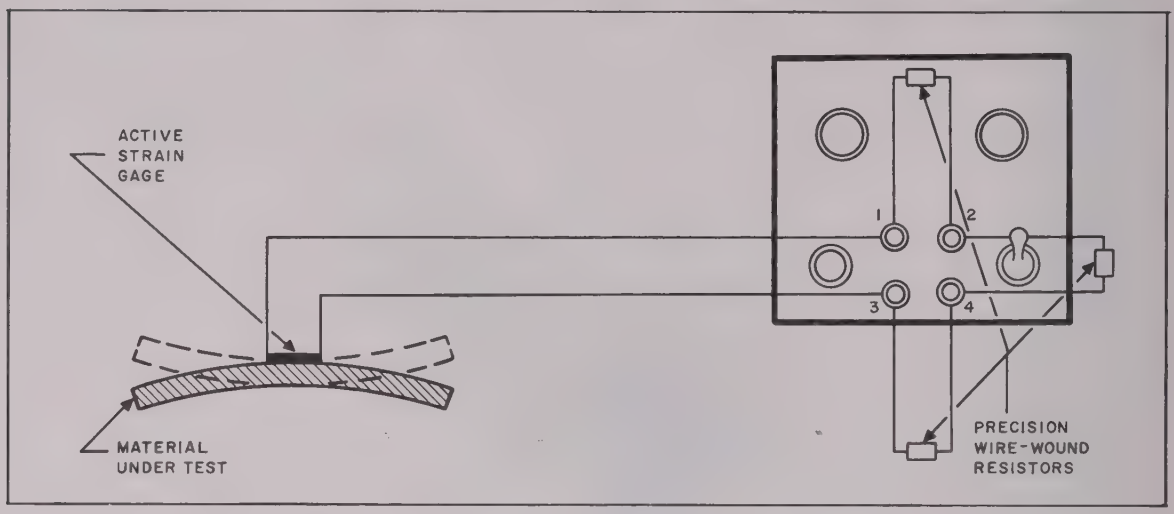


Fig. 6. One Active Strain Gage Connected to the Bridge Balance.

With Temperature Compensation

To compensate for temperature changes in the material being tested, apply a strain gage (of the same resistance value as the active gage) to material of the same composition and in the same temperature zone as the material under test, but not subjected to strain. Connect this inactive gage to the bridge arm adjacent to the active strain gage, as shown in Figure 7.

When one active strain gage is used in a strain recording system, the system is normally calibrated for a sensitivity of 2 microinches per inch of strain per chart millimeter. The internal calibration system in the amplifier permits variation of amplifier gain so that this sensitivity may be obtained for any 50 to 5000 ohm strain gage with a gage factor of 1.7 or higher. If desired, the system may be calibrated for a lower sensitivity.

CONNECTING TWO ACTIVE STRAIN GAGES TO THE BRIDGE BALANCE

A strain recording system using two active strain gages can be calibrated to a sensitivity of 1 microinch per inch of strain per chart millimeter, or twice that of a one-gage system. However, the recorded strain (deflection of the oscillograph pen) depends on connection and mounting of the active strain gages.

Two Active Gages in Adjacent Arms of the Bridge

The recorded strain (output of the bridge circuit) will be twice that for one gage if two active and identical strain gages are connected in adjacent arms and subjected to strains of equal magnitude but of opposite signs. An example of such strain gage application is shown in Figure 8, where two active and identical strain gages are applied to opposite sides of a bending beam or similar piece of material. No temperature compensation is necessary, since changes in resistance value of the gage in compression (resulting from temperature changes in the material under test) are nullified by similar changes in resistance value of the gage in tension.

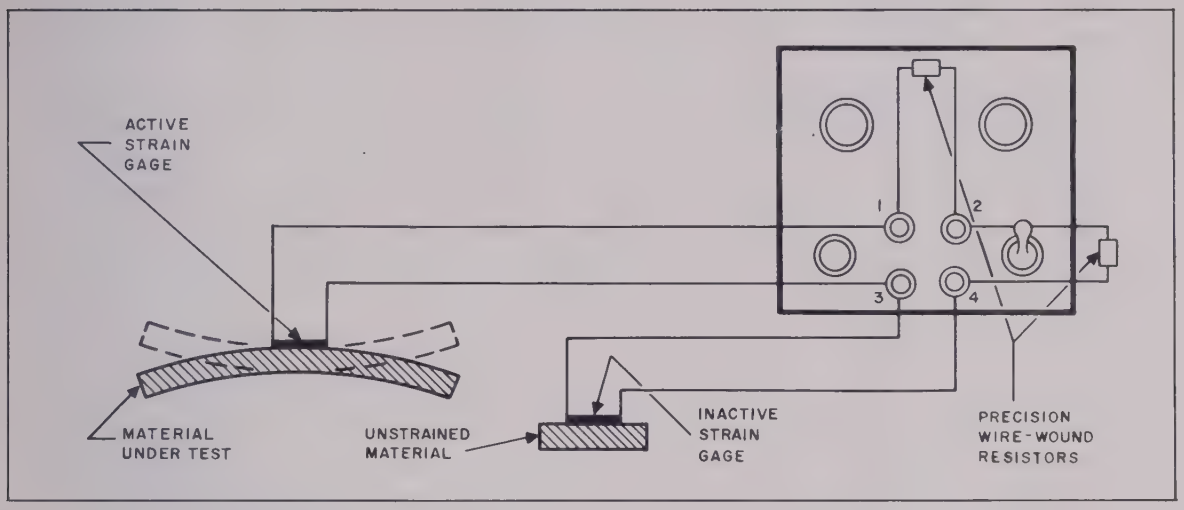


Fig. 7. One Active Strain Gage—Inactive Gage Connected in Circuit for Temperature Compensation.

Where two active strain gages are connected in adjacent arms of the bridge circuit, the output of the bridge is proportional to the algebraic difference between strains in the two gages.

The recorded strain, or output of the bridge circuit, will be zero if two active and identical strain gages are connected in adjacent arms and subjected to strains of equal magnitude and sign.

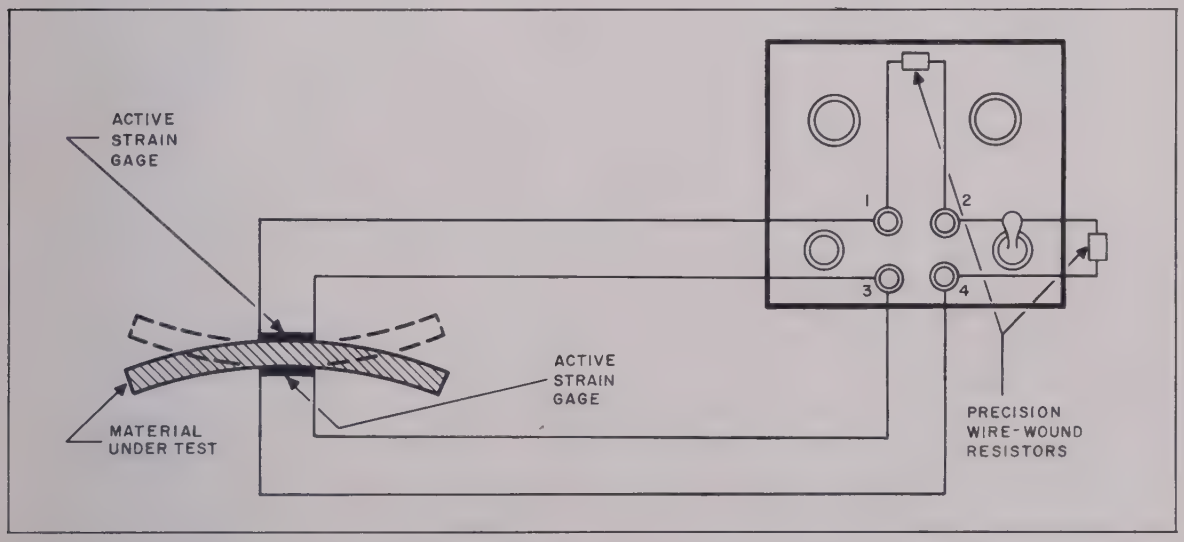


Fig. 8. Two Active Strain Gages—One Measuring Tension, the Other Measuring Compression.

To reverse the direction of pen deflection, transfer all leads from terminal 1 to terminal 4 of the Bridge Balance, and transfer all leads from terminal 4 to terminal 1.

Two Active Gages in Opposite Arms of the Bridge

The recorded strain (output of the bridge circuit) will be twice that for one gage if two active, identical strain gages are connected in opposite arms and subjected to strains of equal magnitude and sign. An example is shown in Figure 9, where two active and identical strain gages are applied side by side on the material under test. If temperature compensation is desired, strain gages of the same gage factor and resistance value as the active gages may be applied to unstressed material of the same composition and in the same temperature environment as the material under test, and connected in the inactive arms of the bridge circuit.

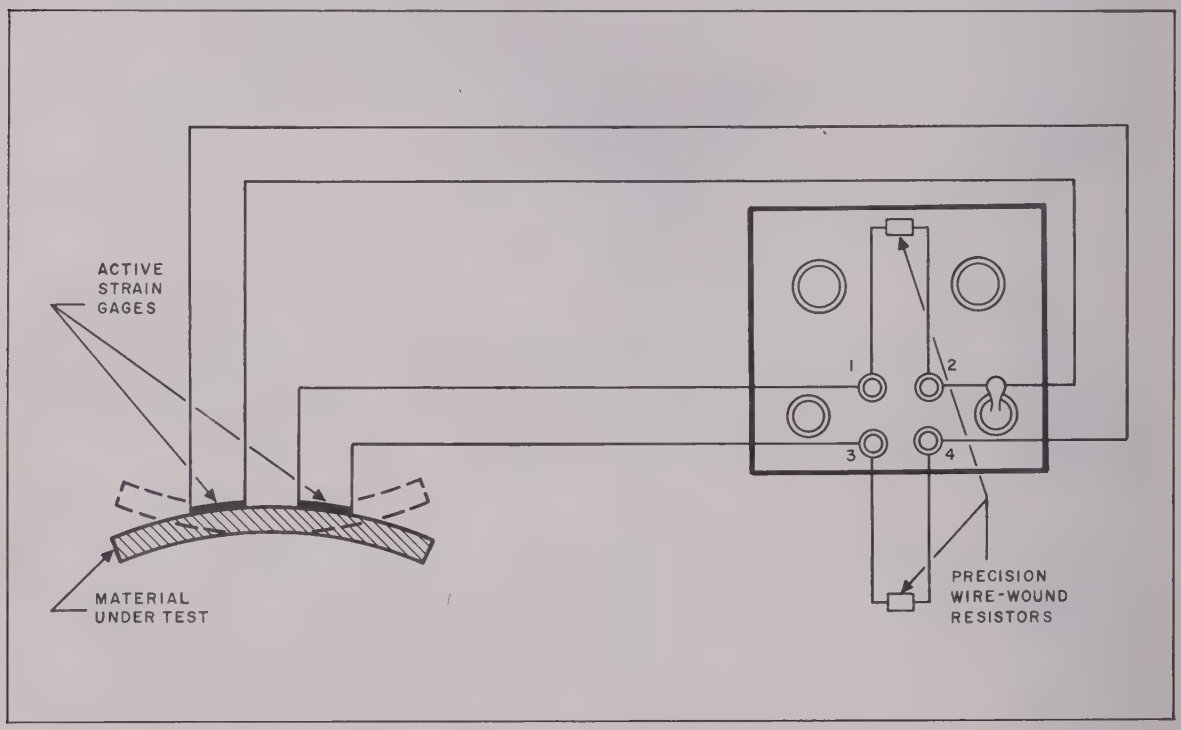


Fig. 9. Two Active Strain Gages Placed Side by Side on Material Under Test.

Where two active strain gages are connected in opposite arms of the bridge circuit, the output of the bridge is proportional to the algebraic sum of strains in the two gages.

The recorded strain, or output of the bridge circuit, will be zero if two active, identical strain gages are connected in opposite arms of the bridge circuit and subjected to strains of equal magnitude and opposite sign.

To reverse the direction of pen deflection, transfer all leads from terminal 1 to terminal 4 of the Bridge Balance, and transfer all leads from terminal 4 to terminal 1.

CONNECTING FOUR ACTIVE STRAIN GAGES TO THE BRIDGE BALANCE

A strain recording system using four active strain gages can be calibrated to a sensitivity of ½ microinch per inch of strain per chart millimeter, or four times that of a one-gage system. However, the recorded strain (deflection of the oscillograph pen) depends on connection and mounting of the active strain gages.

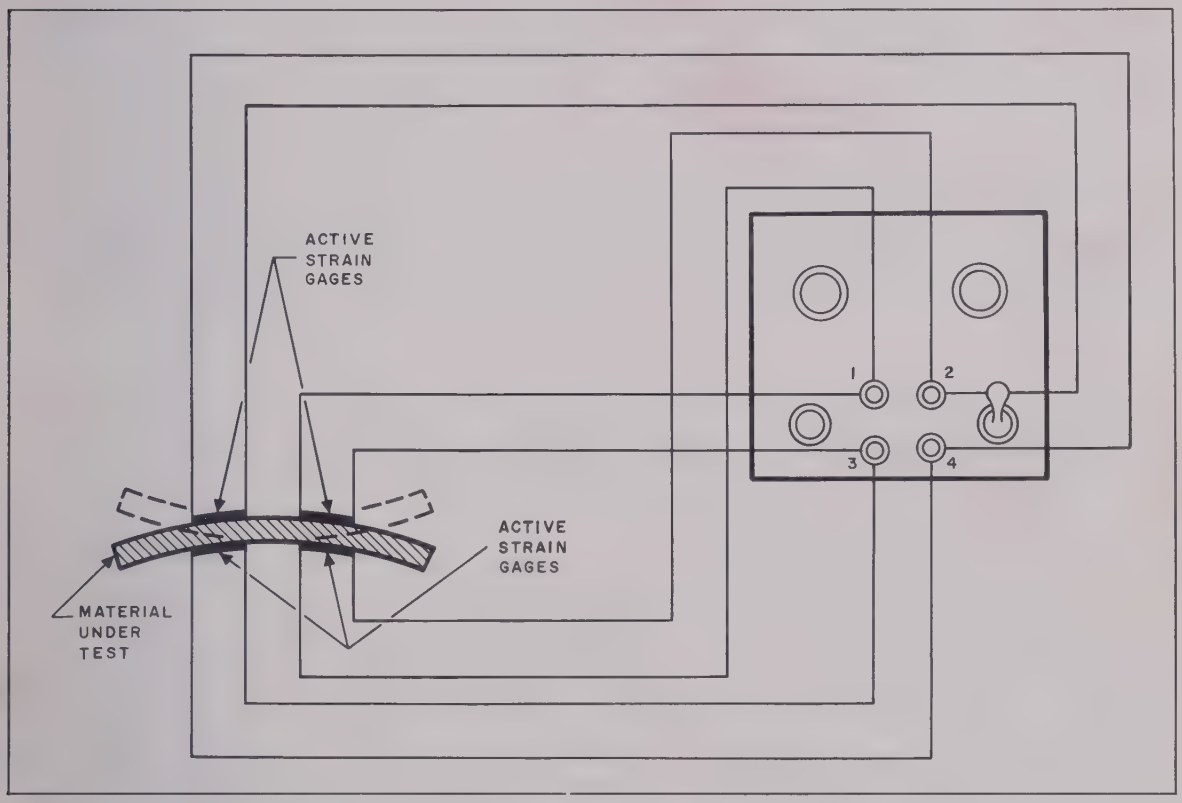


Fig. 10. Four Active Strain Gages—Two Measuring Tension and Two Measuring Compression.

The recorded strain, or output of the bridge circuit, will be four times that for one gage if four active, identical strain gages are connected in the arms of the bridge and subjected to strains of equal magnitude, but of opposite sign for adjacent arms. Figure 10 illustrates such a strain measuring system—at any moment two gages, applied side by side to the material under test, are subjected to tension, while two other gages, applied to the other side of the material, are subjected to compression. Note that the gages in tension and the gages in compression are connected in alternate arms of the bridge circuit. No temperature compensation is necessary, since changes in resistance value of gages in compression (resulting from temperature changes in the material under test) are nullified by similar changes in resistance value of gages in tension.

To reverse the direction of pen deflection, transfer all leads from terminal 1 to terminal 4 of the Bridge Balance, and transfer all leads from terminal 4 to terminal 1.

Output of the four-gage system will be zero if four active, identical gages are subjected to strains of the same magnitude and sign, or if gages in tension are connected to adjacent bridge arms, while gages in compression are also connected to adjacent bridge arms.

CONNECTING A LOAD CELL TO THE BRIDGE BALANCE

The Universal Amplifier and the Bridge Balance may be used with load cells for measuring forces or weighing objects. The load cell should be connected to the Bridge Balance as shown in Figure 11.

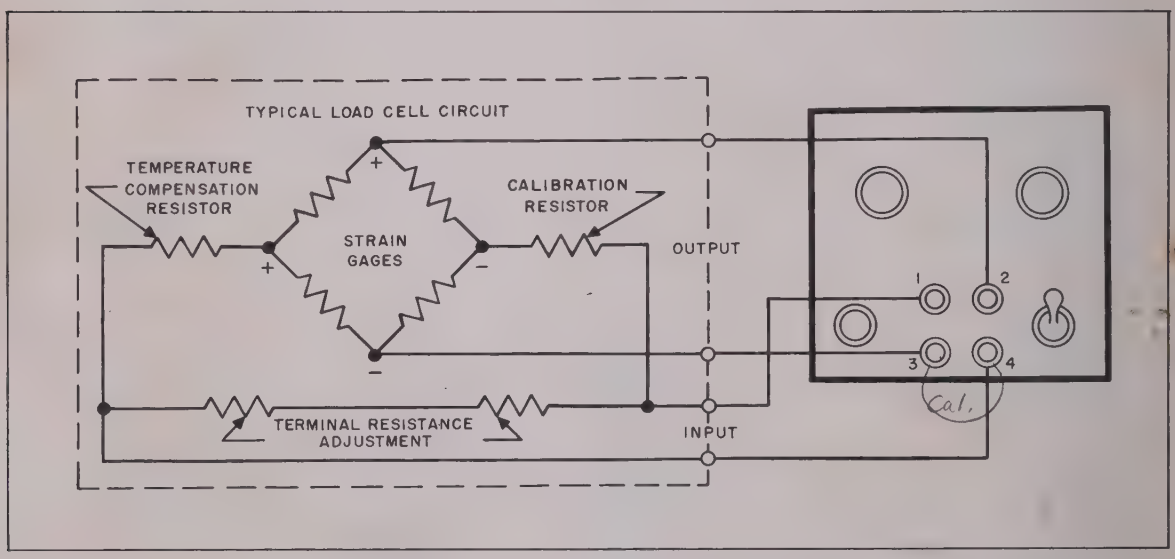


Fig. 11. Typical Load Cell Connected to the Bridge Balance.

Do not connect more than one load cell to each Universal Amplifier in a system.

BALANCING THE UNIVERSAL AMPLIFIER FOR USE WITH THE BRIDGE BALANCE

For satisfactory recording, the Universal Amplifier and strain gage circuit must be balanced and calibrated. The balancing and calibration procedures need not be repeated so long as the same strain gages, in the same positions, are used in a particular strain gage circuit with the Bridge Balance. If information concerning the static component of a complex signal is known or may be disregarded, the balancing procedures described below may be followed with full static load applied to the bridge circuit. In such a case, the balancing procedures serve to cancel the *static* portion of the signal, permitting *only* the *dynamic* portion of the signal to be recorded.

If the static component is not known but is to be considered, balance the system in the "no load" condition, then apply full static load. Note pen deflection caused by application of the static load. Balance the system once more in the usual manner, moving the dynamic recording to chart center. For convenient study of the dynamic recording, increase the sensitivity of the amplifier by turning the CHART MULTIPLIER switch (Fig. 2) to "500", "200", etc.

After following the procedures described under "Balancing and Frequency Compensation," above, see that the Bridge Balance is installed and connected to the strain gage circuit. With the strain gage bridge circuit complete and with no dynamic signal being transmitted from the strain gage circuit to the amplifier, balance the system, proceeding as follows:

1. [illegible]OLTS/CHART LINE switch (Fig. 2) to the "carrier" position. Set the [illegible] switch (Fig. 2) in the "grounded" position. Turn the CHART MULTIPLIER switch (Fig. 2) to the "off" position, and set the SELECTOR switch (Fig. 2) in the "balance" position.
2. Turn the amplifier POWER switch (Fig. 2) to "on" position, and allow 15 minutes for the amplifier to warm up.
3. Turn the oscillograph "on" and, by means of the PEN BIAS control (Fig. 2), move the pen to chart center. *This establishes the center line of the chart paper as the zero reference line for the balancing procedure only.*
4. Turn the CARRIER GAIN control (Fig. 2) to its full counterclockwise (low gain) position.
5. Set the CHART MULTIPLIER switch (Fig. 2) in the "1000" position and, by turning the CARRIER GAIN control (Fig. 2) in a clockwise direction, move the oscillograph pen an appreciable distance (10 to 15 lines) from chart center.

6. Adjust the BALANCE 1 and BALANCE 2 controls on the Bridge Balance (Fig. 4) alternately until the oscillograph pen is, as nearly as possible, on the center line of the chart paper.

If the oscillograph pen cannot be brought to chart center by the above procedure, refer to "Resistive Unbalance" and "Reactive Unbalance" below.

7. Set the CHART MULTIPLIER switch (Fig. 2) in a more sensitive position ("500", "200", etc.) and, by turning the CARRIER GAIN control (Fig. 2) in a clockwise direction, move the pen from chart center. Alternately adjust the BALANCE 1 and BALANCE 2 controls (Fig. 4) to center the pen. Repeat this procedure until the CHART MULTIPLIER switch is in the "1" position and the CARRIER GAIN control is in its extreme clockwise (full gain) position.

At this time it is necessary only to bring the pen to within 15 or 20 lines of chart center. Precise balance is not required, since the accuracy and linearity of the Universal Amplifier are not affected by small unbalances.

8. Turn the SELECTOR switch (Fig. 2) to the "in phase" position. Turn the CHART MULTIPLIER switch (Fig. 2) "off", and re-adjust the pen to chart center by means of the PEN BIAS control (Fig. 2).
9. Set the CHART MULTIPLIER switch (Fig. 2) in the desired position and adjust the pen to chart center by means of the BALANCE 1 control (Fig. 4) on the Bridge Balance, to eliminate any unbalance remaining after completion of step 7, above.

Resistive Unbalance

If it is not possible to move the oscillograph pen through a minimum or null position near the center line of the chart paper by means of the BALANCE 1 control (Fig. 4), remove the Bridge Balance from the amplifier and set the GAGE OHMS switch (Fig. 3) in the next lower resistance position. Install the Bridge Balance in the amplifier and continue with the balancing procedure.

OFF-CENTER ZERO OPERATION OF THE UNIVERSAL AMPLIFIER WHEN USED WITH THE LVDT BALANCE

It is sometimes desirable, when the Universal Amplifier is being used with inductive transducers, to expand the dynamic component of a complex signal for more detailed study. It is possible, by adjusting the zero position of the signal off the chart paper, to cancel the static component and magnify the amplitude of the recording representing the dynamic component. This off-center zero operation permits more accurate interpretation of the dynamic signal. Cancellation of the static signal component is accomplished by means of either the BALANCE 1 control or the BALANCE 2 control on the LVDT Balance (Fig. 15) and the CHART MULTIPLIER switch (Fig. 13) in conjunction with the SELECTOR switch (Fig. 13) on the amplifier front panel. The BALANCE 1 control on the LVDT Balance, used with the SELECTOR switch in the "in phase" position, cancels an inphase or resistive component. The BALANCE 2 control on the LVDT Balance, used with the SELECTOR switch in the "shift phase" position, cancels out the quadrature component in the transducer circuit.

With the amplifier balanced, as described under "Balancing the Universal Amplifier for Use with the LVDT Balance Model RA 5222 00," above, proceed with off-center zero operation, as follows:

1. With the transducer in its null position, turn the SELECTOR switch (Fig. 13) to "in phase" or "shift phase" position (set the switch in the position previously determined as the more sensitive). If the sensitivity is the same in the "in phase" and "shift phase" positions, set the SELECTOR switch in the "in phase" position and use the BALANCE 1 control (Fig. 15).

2. Turn the CHART MULTIPLIER switch (Fig. 13) to "off".

3. Apply the complex load signal to be studied, and turn the CHART MULTIPLIER switch (Fig. 13) to "1000", "500", etc., until the oscillograph pen is off the edge of the chart paper; turn the switch back to the last previous setting.

4. With the appropriate BALANCE 1 or BALANCE 2 control on the LVDT Balance (Fig. 15), adjust the pen trace until the pen records equal amplitudes of the dynamic signal component either side of chart center.

5. Turn the CHART MULTIPLIER switch (Fig. 13) to a more sensitive position ("200", "100", etc.) to increase the amplitude of the dynamic signal component as recorded on the chart.

6. If necessary, re-adjust the recording of the dynamic signal component to the center of the chart by means of the appropriate BALANCE 1 or BALANCE 2 control, as described in step 5, above.

The gain and linearity of the amplifier are not affected if the static component cancellation at any CHART MULTIPLIER switch setting is within the range of the BALANCE 1 and BALANCE 2 controls on the LVDT Balance (Fig. 15).

OPERATION AS A MEDIUM GAIN D. C. AMPLIFIER

In addition to use with the Bridge Balance Model RA 5212 00 and the LVDT Balance Model RA 5222 00, the Brush Universal Amplifier is suited for use as a medium gain d.c. amplifier. In such application, the d.c. amplifier section alone is used, while the carrier amplifier section remains idle.

SINGLE-ENDED AND BALANCED INPUT SIGNALS APPLIED TO THE D.C. AMPLIFIER SECTION

The d.c. amplifier section of the Universal Amplifier will accept either single-ended or "balanced" input signals. A single-ended signal is obtained from a circuit having one terminal already at ground potential, or a circuit which will not be disturbed if one terminal is connected to ground or to the amplifier chassis.

A "balanced" or double-ended signal, as used in connection with the d.c. amplifier section, is a signal obtained from a circuit which will be disturbed when one terminal is connected to ground. For example, the voltage across the secondary winding of a transformer with an intermediate tap connected to ground may be defined as a "balanced", or double-ended signal. Grounding of either output terminal of such a circuit would short circuit the transformer.

Examples of single-ended and "balanced" input connections are shown in Figure 17.

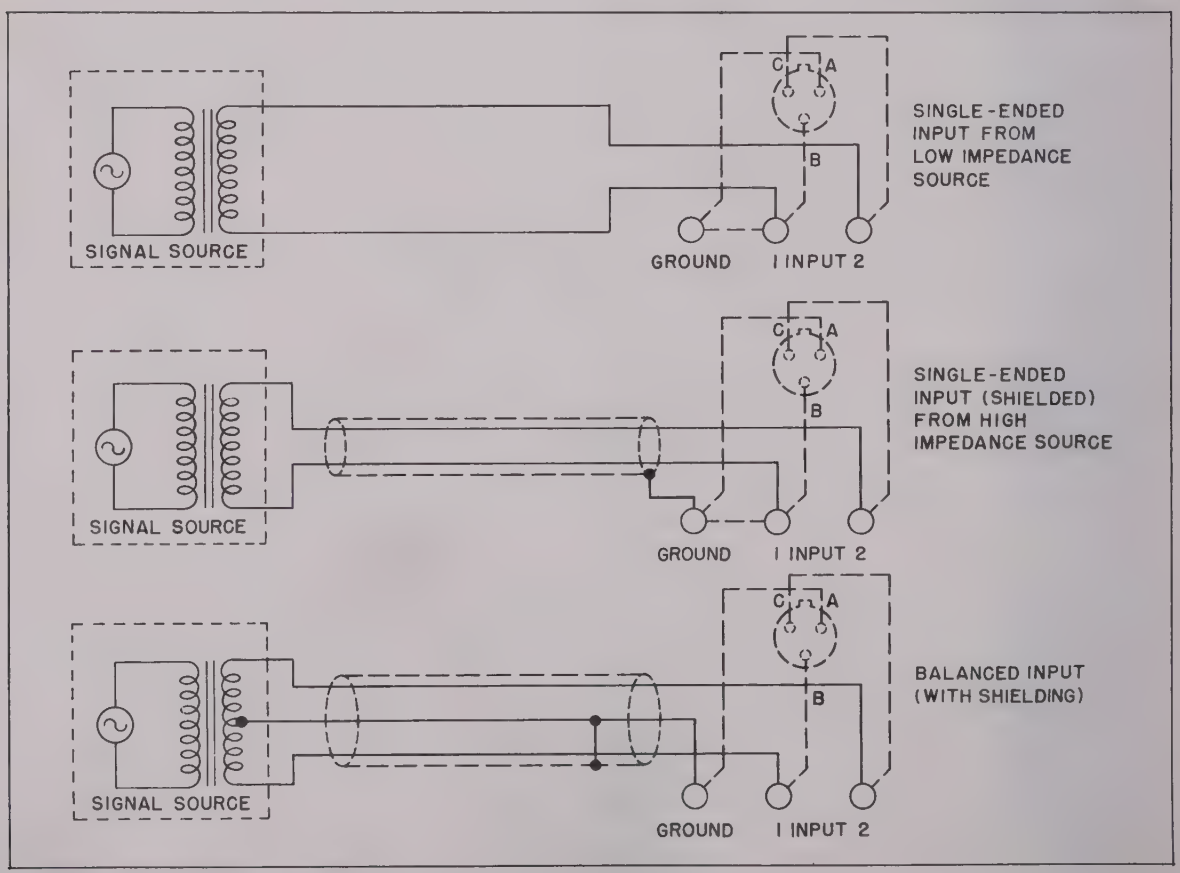


Fig. 17. Typical Single-Ended and Balanced Signal Sources.

When one side of the signal circuit is connected to ground a considerable distance from the amplifier input and the signal level is low, it is possible that "ground currents" through the "ground" connection to the amplifier will produce sufficient voltage drop between the signal source and the amplifier to introduce spurious signals. In such a case it is advisable to set the INPUT switch in the "balanced" position and use the "balanced" input terminals (INPUT 1 and INPUT 2) with one terminal connected to ground at the signal source as shown in Figure 18. Such connections eliminate the "ground loop" in the input circuit.

USE OF THE D.C. AMPLIFIER SECTION WITH AN OSCILLOSCOPE

When the d.c. amplifier section is used with an oscilloscope or similar equipment, amplifier output is taken from pins "B" and "C" of the OUTPUT connector on the rear panel (Fig. 1).

WARNING:

The output terminals of this amplifier are 30 volts (d.c.) above chassis and should not be connected to any load in which either terminal is grounded.

In cases where extended frequency response is desired (when the d.c. amplifier section is being used with an oscilloscope or similar equipment), turn the PEN COMPENSATION control (Fig. 1) fully counterclockwise, noting that a switch is actuated at the full counterclockwise position. The voltage gain of the amplifier, when the PEN COMPENSATION control is in full counterclockwise position, is in excess of 30.

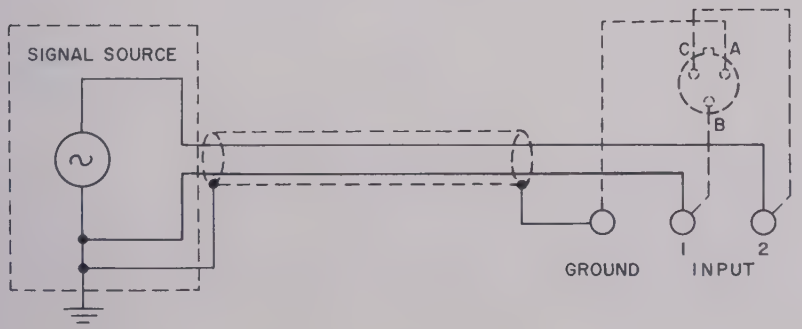


Fig. 18. Connection of Single-Ended Input from Remote Signal Source.

CALIBRATION OF THE D.C. AMPLIFIER SECTION

After balancing the d.c. amplifier section and matching it with a penmotor (see "Frequency Compensation", above), calibrate the d.c. amplifier section as follows:

1. Turn the VOLTS/CHART LINE switch (Fig. 13) "off" and set the INPUT switch (Fig. 13) in the "balanced" position. If the oscillograph pen is not on the center line of the chart, repeat the procedures described under "Balancing the D.C. Amplifier Section", above.
2. Turn the VOLTS/CHART LINE switch (Fig. 13) to the "calibrate" position and adjust the CALIBRATION control (Fig. 13) as necessary to obtain a pen deflection of 20 chart lines left of center. Turn the VOLTS/CHART LINE switch to "off".
3. Check 20 line deflection by again turning the VOLTS/CHART LINE switch (Fig. 13) to the "calibrate" position. If necessary, readjust the CALIBRATION control (Fig. 13) to obtain a pen deflection of 20 chart lines.

PRELIMINARY OPERATION OF THE D.C. AMPLIFIER SECTION

Connect the d.c. amplifier section to a signal source of known amplitude by means of the GROUND, INPUT 1, and INPUT 2 terminals (Fig. 13) on the front panel, or by means of the D.C. INPUT connector (Fig. 1) on the rear panel, using shielded leads when the impedance of the signal source is high.

When connecting a single-ended input at the front panel, connect the "hot" side (in reference to ground) to the INPUT 2 terminal (Fig. 13). Connect the side of the signal to be grounded to the GROUND terminal (Fig. 13) or the INPUT 1 terminal (Fig. 13).

When connecting a single-ended input at the rear panel, connect the "hot" side of the signal to pin "C" of the D.C. INPUT connector (Fig. 1), and connect the side of the signal to be grounded to pin "B" or pin "A". (When the INPUT switch is in the "grounded" position, pin "B" is shorted to pin "A", so that either pin may be used as a ground connection.)

To connect a balanced input at the front panel, connect one side of the input circuit to the INPUT 1 terminal (Fig. 13), and the other side to the INPUT 2 terminal (Fig. 13). To connect a balanced input at the rear panel, connect one side of the input circuit to pin "B" of the D.C. INPUT connector (Fig. 1), and the other side to pin "C". The ground point of the signal source, if available, as well as signal cable shielding, should be connected to the GROUND terminal on the front panel, or to pin "A" of the D.C. INPUT connector on the rear panel.

NORMAL OPERATION OF THE D.C. AMPLIFIER SECTION

1. Turn the VOLTS/CHART LINE switch (Fig. 13) successively to "10", "5", etc., to reach the desired sensitivity. The signal voltage is equal to the number of lines of pen deflection, from the signal zero position, multiplied by the setting of the VOLTS/CHART LINE switch.
2. Adjust the oscillograph pen to the desired position on the chart paper by means of the PEN BIAS control (Fig. 13) if the INPUT switch (Fig. 13) is in the "grounded" position. No adjustment can be made if the INPUT switch is in the "balanced" position. See " Balancing the D.C. Amplifier Section", above.

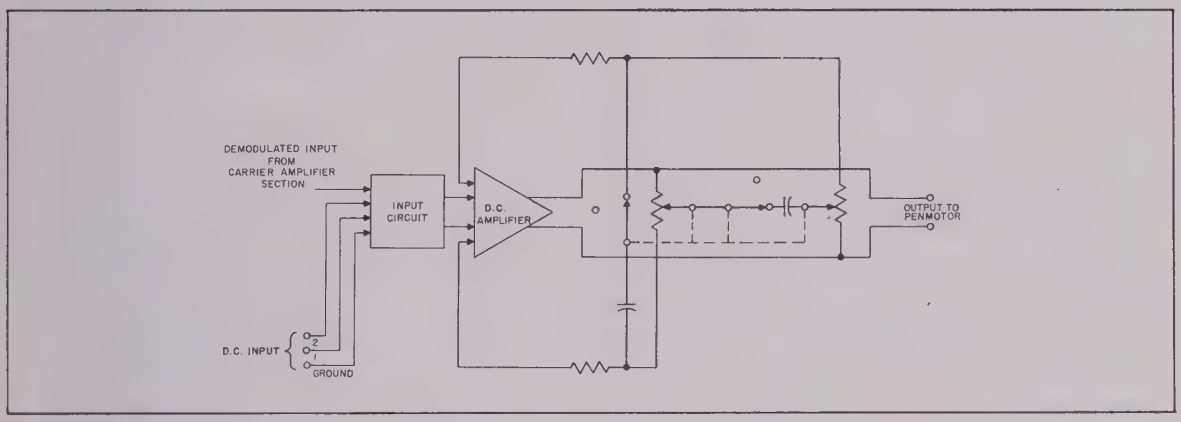


Fig. 28. Block Diagram—Output Circuit. (D.C. Amplifier Section).

arms of the bridge, so that the penmotor coil is, in effect, the load across the bridge. The signals which appear at the input grids of the bridge circuit are equal in amplitude, but opposite in polarity. A voltage divider applies a portion of each bridge input signal to one tube section. This tube section and the tube section receiving the full input signal are on opposite arms of the bridge circuit. (For example, if the full bridge input signal is applied to a grid of V-8, a portion of this same signal is applied to a grid of V-9, on the opposite arm of the bridge circuit.) Application of input voltages to the bridge circuit provides a low impedance series current path through the two tube sections to which positive voltages are applied, and through the penmotor. This causes deflection of the oscillograph pen. Reversing polarity of the input voltages produces a current path through the other two tube sections and through the penmotor. Because the direction of current flow through the penmotor coil has been reversed by the change in polarity of the input signals, the pen is now deflected in the opposite direction.

OUTPUT CIRCUIT

Negative feedback paths from the output terminals of the bridge circuit to the summing points in the plate circuits of the input tube (V-5) provide approximately 26 db of d.c. feedback to stabilize over-all gain in the amplifier circuit (Fig. 28). The a.c. negative feedback around these paths may be reduced with increasing frequency by two capacitors connected across the feedback networks. Compensation of the frequency response of the amplifier to match that of the penmotor is accomplished by varying the effect of one of these capacitors, through the use of a dual potentiometer in the feedback network. A switch is provided on this dual potentiometer to disconnect the two capacitors across the feedback networks. This produces optimum amplifier frequency response from d.c. to 5 kc for use of the d.c. amplifier section with oscilloscopes or other similar devices.

POWER SUPPLY

An electronically-regulated power supply with a wide frequency range is used in the Universal Amplifier Model RD 5612 00, permitting operation from power lines in the frequency range of from 50 to 2000 cps. The power supply provides series-type regulation for plate voltage, and also provides an a.c. filament voltage. High voltage from the transformer (T-4) is rectified in a 6BW4 tube (V-10) and applied to the plates of the 6080 series regulator tube (V-11). (The load is connected to the cathodes of the series regulator tube.) This output voltage is compared at the grid (Pin 7) of the 5751 tube (V-12) with voltage from an OA2 reference tube (V-13). This comparison determines whether or not the output voltage of the + B supply agrees with the desired voltage, as preset on the potentiometer (R-129). If not, a voltage change proportional to the error appears at the plate (Pin 6) of the 5751 tube. This voltage is amplified by the other section of the 5751 tube and applied as a bias voltage to the 6080 series regulator tube. This correcting action is continuous, regulating the output voltage of the power supply for varying conditions of load and input voltage.

The + B output of the power supply is connected to the — B output by a voltage divider (R-133, R-134, R-135, and R-136), which establishes the potential from —B to chassis ground for operation of the double-ended amplifier system (carrier amplifier and d.c. amplifier sections). This voltage divider also provides pen bias voltage used for positioning the oscillograph pen. Filament voltages for the amplifier system are derived from transformers T-4 and T-5. An interference filter, located at the power input of the power supply, minimizes the effect of any transients present in the power line.

This amplifier has been balanced and adjusted accurately before shipment from the factory, and should give long, trouble-free service. For any servicing other than that described in this manual, the instrument should be sent to one of the Brush service facilities (listed on the Warranty page), where it can be restored to original condition. See Shipping Instructions following the Table of Contents.

TUBE REPLACEMENT

To replace any faulty tube, disconnect all cables and expose the chassis. If the amplifier is in a Portable Case, remove screws from the top and bottom of the case, and remove the mounting screws from the front panel of the amplifier. If the amplifier is rack mounted, remove the mounting screws from the front panel, withdraw the amplifier from the rack, and remove the top portion of the wrap-around cover. Do not remove screws securing the front panel to the amplifier chassis. In either case, all tubes will be exposed (Fig. 29).

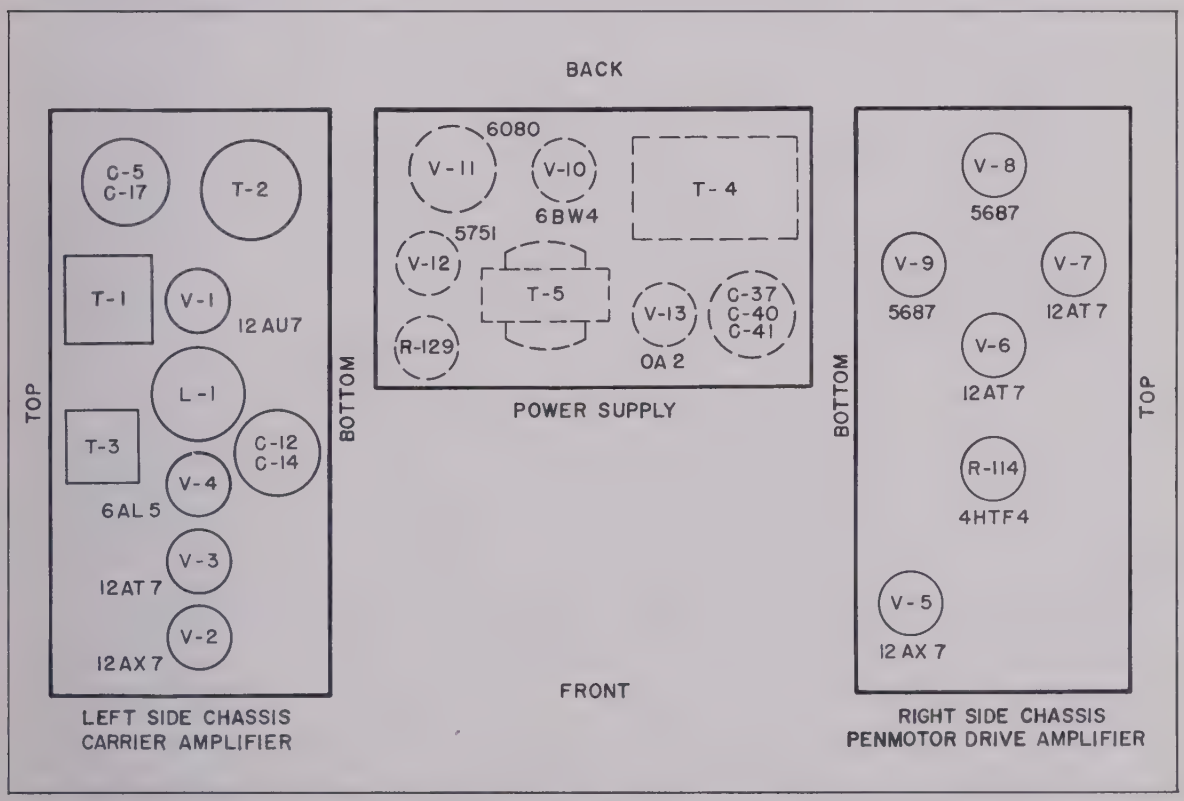


Fig. 29. Tube Layout.

LEFT SIDE CHASSIS

If any tubes are replaced in the left side chassis, rebalance the carrier amplifier section as described under "Carrier Detector Balance Adjustment", below.

RIGHT SIDE CHASSIS

Following the replacement of any tube in the d.c. amplifier section, the amplifier must be balanced, as described below:

1. Connect the OUTPUT connector of the amplifier (Fig. 1) with the oscillograph input connector by means of the amplifier-to-oscillograph signal cable.
2. Connect the amplifier and oscillograph to their power source, and turn the amplifier POWER switch (Fig. 13) to "on". Allow 15 minutes for the amplifier to warm up.
3. Turn the oscillograph "on" at slow chart paper speed (to conserve chart paper).
4. Set the INPUT switch (Fig. 13) in the "balanced" position.
5. Turn the CALIBRATION control (Fig. 13) full clockwise, and bring the oscillograph pen approximately to chart center by means of the TUBE ADJUST control on the rear panel of the amplifier (Fig. 1).
6. Turn the BALANCE control, on the rear panel of the amplifier (Fig. 1), to its extreme counterclockwise position. Rapidly rotate the CALIBRATION control (Fig. 13), counterclockwise, then clockwise, while turning the BALANCE control slowly clockwise until no pen deflection is noted.
7. Center the pen on the chart by means of the TUBE ADJUST control on the rear panel of the amplifier (Fig. 1).

POWER SUPPLY CHASSIS

Following the replacement of any tube in the power supply chassis (Fig. 29), adjust +B voltage to 235 volts by means of the potentiometer control R-129 (measured from the junction of C-38 and R-130 to pin 5 of the OA2 tube V-13).

Following any tube replacement in the Universal Amplifier, install the wrap-around cover (if any) on the amplifier, and return the amplifier to its rack or Portable Case.

CARRIER LEVEL ADJUSTMENT

Oscillator output amplitude may be adjusted, if necessary, by means of the OSCILLATOR AMPLITUDE control on the rear panel of the Universal Amplifier (Fig. 1). If the Bridge Balance Model RA 5212 00 (Fig. 4) is used, oscillator output voltage should be 3.0 volts (RMS) measured across terminals 1 and 4 of the Bridge Balance. If the LVDT Balance Model RA 5222 00 (Fig. 15) is used, oscillator output voltage should be 180 mv (RMS) measured across the "primary" and "common" terminals of the LVDT Balance. The above measurements should be made with a Ballantine vacuum tube voltmeter (VTVM) or equivalent.

CARRIER DETECTOR BALANCE ADJUSTMENT

The carrier amplifier detector reference level is adjusted at the factory. However, after a tube change or after a change in the type of balance box used with the amplifier, excessive pen offset may be noted as the SELECTOR switch (Fig. 13) is turned from the "balance" position to the "in phase" or the "shift phase" position. To eliminate such pen offset, re-adjust the detector reference level, as follows:

1. Balance the amplifier as described under "Balancing the Universal Amplifier for Use with the Bridge Balance Model RA 5212 00" or "Balancing the Universal Amplifier for Use with the LVDT Balance Model RA 5222 00", above.

2. Turn the CHART MULTIPLIER switch (Fig. 2) to "off".
3. Set the INPUT switch (Fig. 2) in the "grounded" position.
4. Turn the VOLTS/CHART LINE switch (Fig. 2) to "off".
5. Note the position of the pen on the oscillograph chart.
6. Turn the SELECTOR switch (Fig. 2) to the "in phase" position when using the Bridge Balance, or to the "shift phase" *or* "in phase" position when using the LVDT Balance.
7. Turn the VOLTS/CHART LINE switch (Fig. 2) to the "carrier" position.
8. By means of the DETECTOR BALANCE control on the rear panel of the amplifier (Fig. 1), adjust the pen trace to the position noted in step 5, above.

CORRECTION FOR POWER LINE TRANSIENTS

The Brush Universal Amplifier Model RD 5612 00 features an electronically-regulated power supply, heavy decoupling, and an internal interference filter. However, because of the extremely high gain of the carrier amplifier section, line voltage transients, generated by electric typewriters, adding machines, universal motors, etc., may be amplified and recorded. To prevent the recording of such transients, eliminate their source.

Power line transients can often be eliminated by connecting offending electrical equipment to a power line branch separate from the amplifier power source, and locating such equipment at least 20 feet from the amplifier.

Often the effect of line transients on the amplifier can be eliminated through the use of a filter on the transient source. Such a filter might be a fixed capacitor of predetermined optimum value for relays and event markers; an LC (inductance-capacitance) filter network, available commercially, for electric typewriters, adding machines, and universal motors; or a source filter with interference attenuation characteristics appropriate for the specific machine, available from manufacturers of electric typewriters and adding machines.

If transients cannot be eliminated or reduced satisfactorily at their source, line pulse amplitudes can often be reduced by connecting a commercial type interference filter across power line terminals of the amplifiers.

MODIFICATION OF POWER TRANSFORMER CONNECTIONS FOR OPERATION AT 95 TO 115 VOLTS

The Brush Universal Amplifier is normally wired to operate on a power line voltage of from 105 to 125 volts. If the available power source is from 95 to 115 volts, a slight modification in the wiring of the power transformer (T-4) will adapt the amplifier to operation from such a power source. To make this modification, proceed as follows:

1. Disconnect the input power lead and capacitor lead from terminal "3" of the power transformer (T-4). Connect these two leads to terminal "2" of the power transformer. Refer to the Tube Layout (Fig. 29), and to the Schematic Diagram.
2. Re-solder to terminal "3" of the power transformer (T-4) that lead connecting terminal "3" to the separate filament transformer (T-5).

The above modification will be made at the factory if requested at time of ordering.

TROUBLE SHOOTING

The chart below lists symptoms and probable causes of improper operation of the amplifier, or failure of the amplifier to operate, as well as probable remedies for unsatisfactory operating conditions. The conditions described in the chart are for a Universal Amplifier Model RD 5612 00, connected to a correctly adjusted, operating Brush oscillograph, and operating from a 60 cps 115 volt power source. Procedures suggested in the "Remedy" column may be performed by operating personnel.

GENERAL

SYMPTOM	CAUSE	REMEDY
1. Amplifier does not operate; pilot lamp does not light.	a. Power cable disconnected. b. Fuse open. c. POWER SWITCH turned off. d. No line voltage.	a. Connect to power source. b. Replace fuse. c. Turn POWER SWITCH on. d. Connect to proper power source.
D. C. AMPLIFIER SECTION		
1. D.C. Amplifier section inoperative, pilot lamp lights.	a. Defective amplifier-to-oscillograph cable. b. Inoperative 6BW4, 6080, 5751, 12AX7, 12AT7-WA, or 5687 tubes; inoperative 4HTF4 resistor.	a. Repair cable. b. Replace tube or resistor.
2. PEN BIAS control inoperative with INPUT switch in "grounded" position and VOLTS/CHART LINE switch in "off" position.	a. 12AX7 tube or 4HTF4 resistor inoperative. b. Defective contacts on INPUT switch.	a. Replace defective tube or resistor. b. Clean contacts or replace switch.
3. TUBE ADJUST control on rear panel inoperative during balancing of amplifier per Operating Instructions.	a. 12AX7, 12AT7WA, or 5687 tubes inoperative.	a. Replace defective tubes.
4. BALANCE control on rear panel inoperative during balancing of amplifier per Operating Instructions.	a. 12AX7 tube or 4HTF4 resistor inoperative.	a. Replace defective tube or resistor.
5. Oscillograph pen off chart or deflected far to one side.	a. 5687,12AT7WA,or12AX7 tubes inoperative. b. Grounded lead to pen-motor.	a. Replace defective tubes. b. Eliminate ground.
6. Amplifier can be balanced, but drift exceeds ¼ mm of chart per hour.	a. +B voltage supply not regulating properly. b. Excessive line voltage variation. c. 12AX7, 12AT7WA, or 5687 tube intermittent or producing low emission. d. Defective 4HTF4 resistor.	a. Refer to "Power Supply" section of this chart. b. Connect amplifier to proper power source. c. Replace defective tube. d. Replace resistor.

SYMPTOM	CAUSE	REMEDY
7. 120 cps output indicated on oscillograph chart without input to amplifier.	a. Filter capacitor defective. b. Shorted 6080 tube. c. Inoperative OA2 or 5751 tube.	a. Replace filter capacitor. b. Replace defective tube. c. Replace defective tubes.
8. 60 cps output indicated on oscillograph chart without input to amplifier.	a. Cathode-heater leakage, any tube in d.c. amplifier section.	a. Locate and replace defective tube.
9. Random output indicated on oscillograph chart without input to amplifier.	a. Noisy tube. b. Noisy components. c. Oscillation in OA2 tube.	a. Locate and replace defective tube. b. Locate and replace defective components. c. Replace OA2 tube.
10. Maximum calibrate level less than 20 lines.	a. Weak 12AX7, 12AT7WA, 5687, 6BW4, or 6080 tube. b. Dirty calibrate cell contacts. c. Inoperative calibrate cell.	a. Locate and replace defective tube. b. Clean calibrate cell contacts. c. Replace calibrate cell.
11. Incorrect values for VOLTS/CHART LINE switch steps.	a. Changed resistance value in attenuator resistors. b. Grounded components in attenuator assembly.	a. Locate and replace defective resistors. b. Locate and eliminate grounds.
12. Amplifier cannot be frequency compensated.	a. Improper frequency compensation procedure. b. Defective dual potentiometer, switch, or capacitor in compensation network.	a. Refer to Operating Instructions for proper procedure. b. Locate and replace defective components.
13. Poor d.c. linearity.	a. Weak tube in d.c. amplifier section. b. Defective penmotor.	a. Locate and replace defective tube. b. Replace penmotor or oscillograph.
CARRIER AMPLIFIER SECTION		
1. D.C. Amplifier section operates normally. Output indicated on oscillograph chart (without input to amplifier) when the VOLTS/CHART LINE switch is turned to the "carrier" position, INPUT switch is in "grounded" position, CHART MULTIPLIER switch is in "off" position, CARRIER GAIN control is fully clockwise, and the SELECTOR switch is in the "in phase" position.	a. DETECTOR BALANCE control improperly adjusted. b. Inoperative 6AL5 tube. c. Defective 12AX7, 12AU7, or 12AT7WA tube. d. Defective components in detector or amplifier circuits.	a. Refer to the Operating Instructions for proper adjustment procedure. b. Replace defective tube. c. Replace defective tube. d. Locate and replace defective components.

SYMPTOM	CAUSE	REMEDY
2. Amplifier operates, but shows low sensitivity in "carrier" operation.	a. Inadequate voltage output to bridge or LVDT transducer.	a. Adjust the OSCILLATOR AMPLITUDE control to obtain proper carrier level. If the adjustment above does not correct the low sensitivity condition, replace the 12AU7 (oscillator) tube. Locate and eliminate shorts in sync cables which would interfere with oscillator operation.
	b. Weak tube in carrier amplifier section.	b. Locate and replace defective tube.
	c. CALIBRATION RESISTOR value incorrect for Strain gage resistance used.	c. Check specifications for proper value of CALIBRATION RESISTOR.
3. Oscillograph chart indicates non-linearity in "carrier" operation.	a. Bridge circuit not properly balanced.	a. Balance the system as described in Operating Instructions.
	b. DETECTOR BALANCE control not properly adjusted.	b. Refer to Operating Instructions for proper adjustment procedure.
	c. Defective diode in 6AL5 tube.	c. Replace defective tube.
	d. Carrier detector level not adjusted properly.	d. Adjust carrier detector level as specified for the transducer being used.
	e. Weak 12AX7, 12AU7, or 12AT7WA tube.	e. Locate and replace defective tubes.
4. Beat note appears on chart when the amplifier is used in multi-channel operation.	a. No sync connection between oscillators.	a. Interconnect all active oscillators through SYNC connectors.
	b. One amplifier turned off while still connected in system "sync" circuit.	b. Turn on all amplifiers or disconnect sync cable from unused amplifier.
5. Incorrect values for CHART MULTIPLIER steps.	a. Changed resistance value for resistors in switch assembly.	a. Locate and replace defective resistors.
	b. Grounded resistor or contact on CHART MULTIPLIER switch assembly.	b. Locate and eliminate grounds.
POWER SUPPLY		
1. +B to −B regulated voltage varies, or is erratic.	a. Insufficient line voltage.	a. Connect amplifier to proper power source.
	b. Defective 6BW4, 6080, 5751, or OA2 tube.	b. Locate and replace defective tubes.
	c. Inoperative filter capacitors.	c. Locate and replace defective filter capacitors.
	d. Defective components in power supply.	d. Locate and replace defective components.

PARTS IDENTIFICATION

Components of the Universal Amplifier may be identified by means of Figures 30 through 40 (below). The symbols appearing on these illustrations are correlated with the Parts List and the Schematic Diagram. In addition to identification of parts, Figure 37 includes a color code for connection of wiring to the printed wiring board in the medium gain d.c. amplifier section.

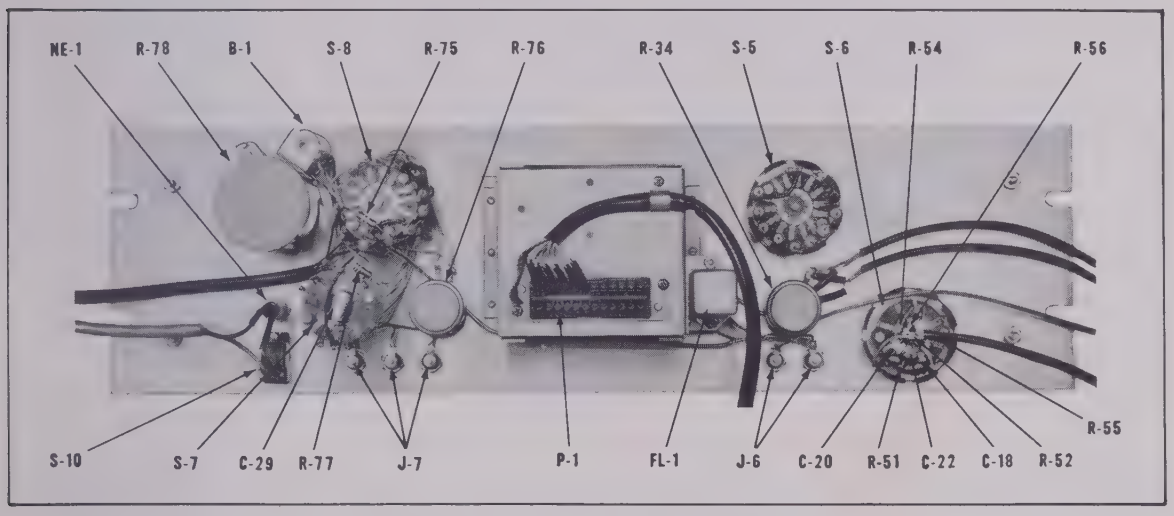


Fig. 30. Rear View—Front Panel Assembly.

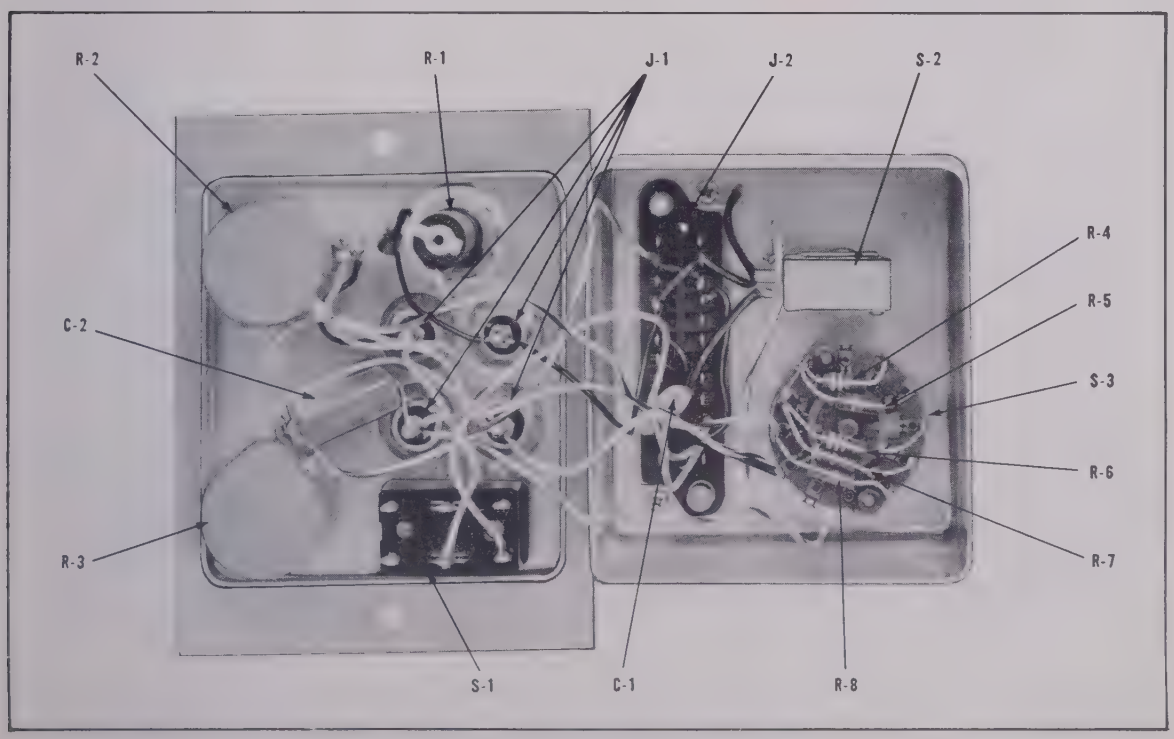


Fig. 31. Internal View—Bridge Balance Model RA 5212 00.

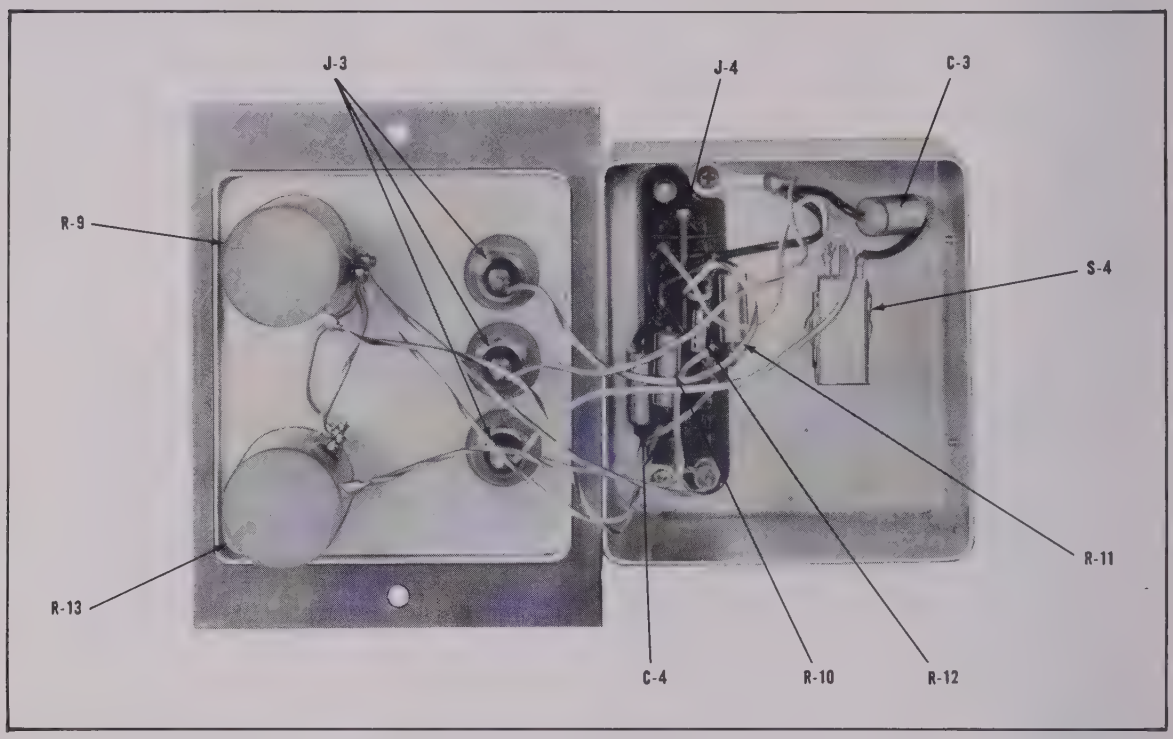


Fig. 32. Internal View—LVDT Balance Model RA 5222 00.

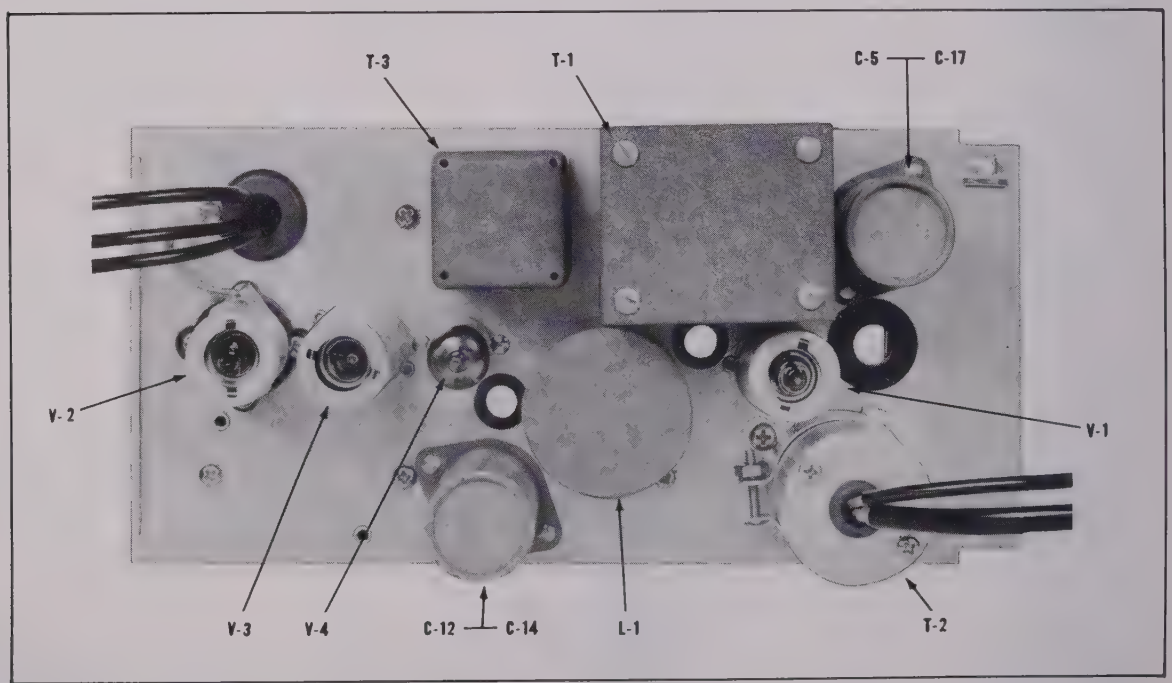


Fig. 33. Inside View—Left Side Chassis.

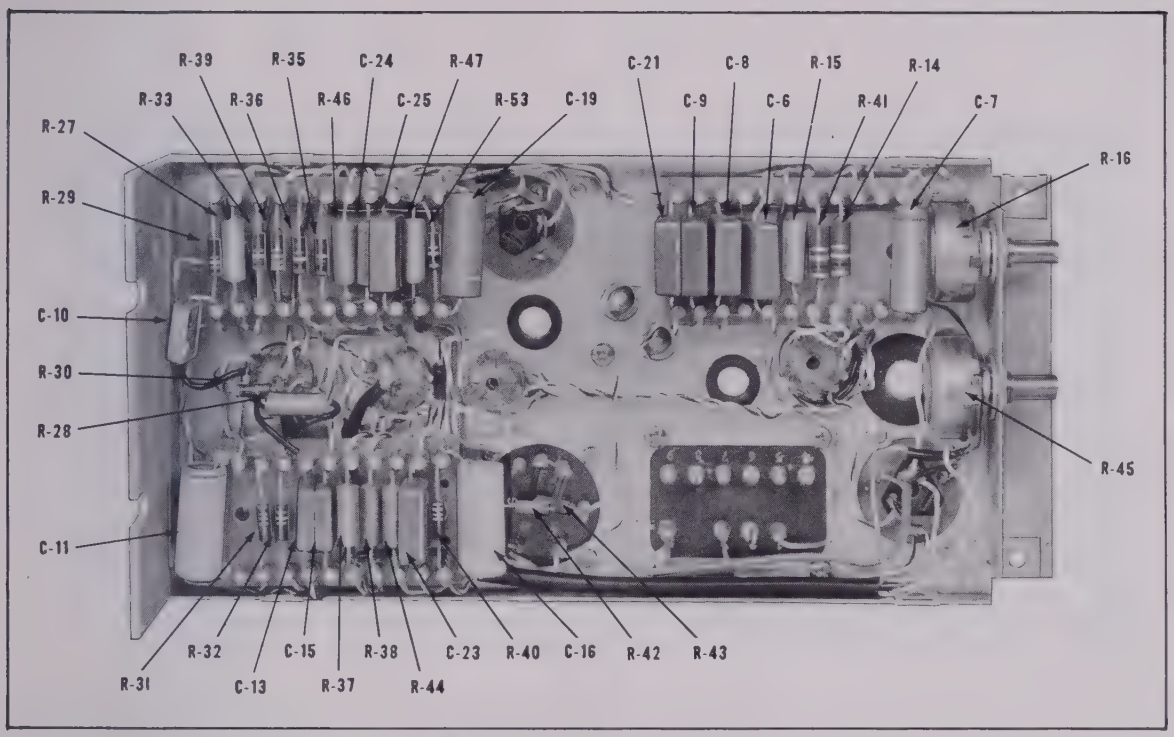


Fig. 34. Outside View—Left Side Chassis.

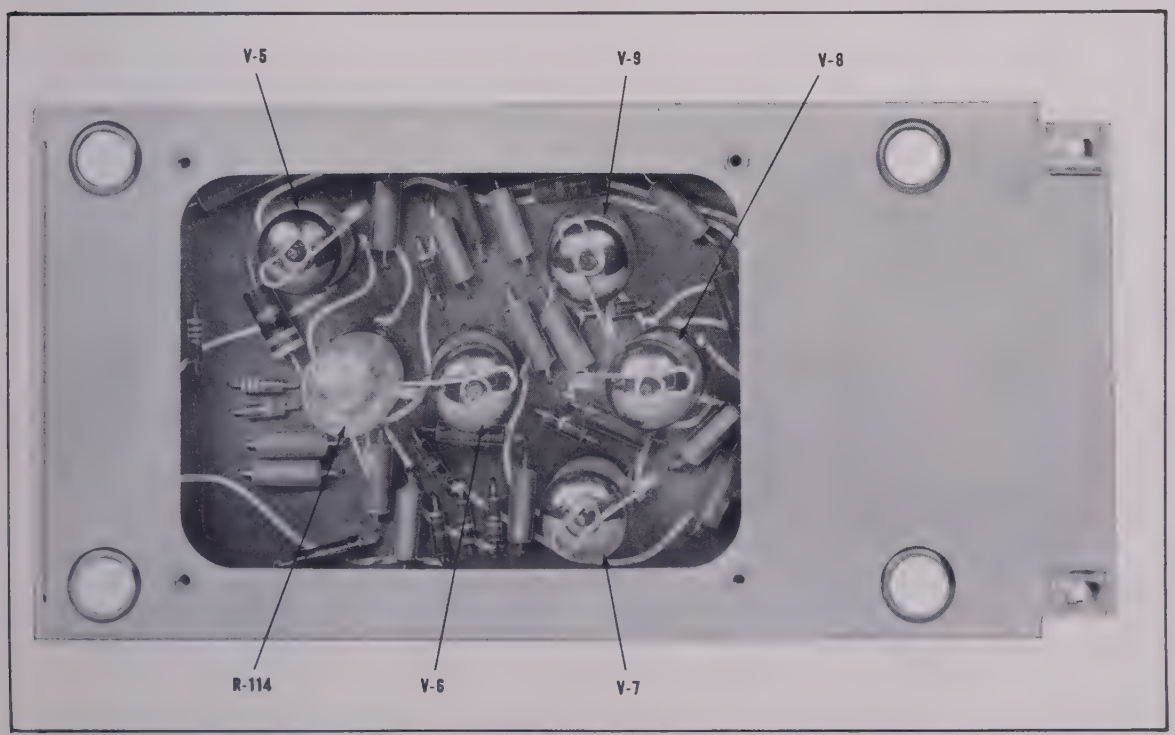


Fig. 35. Inside View – Right Side Chassis.

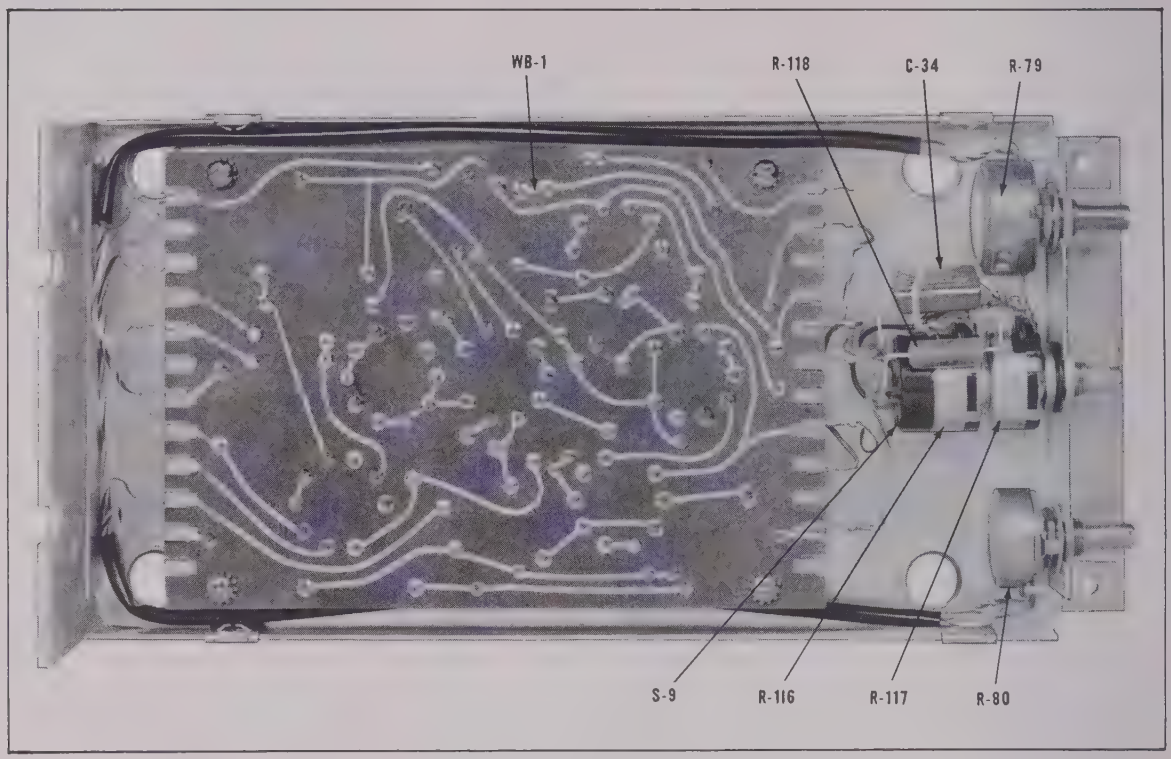


Fig. 36. Outside View—Right Side Chassis.

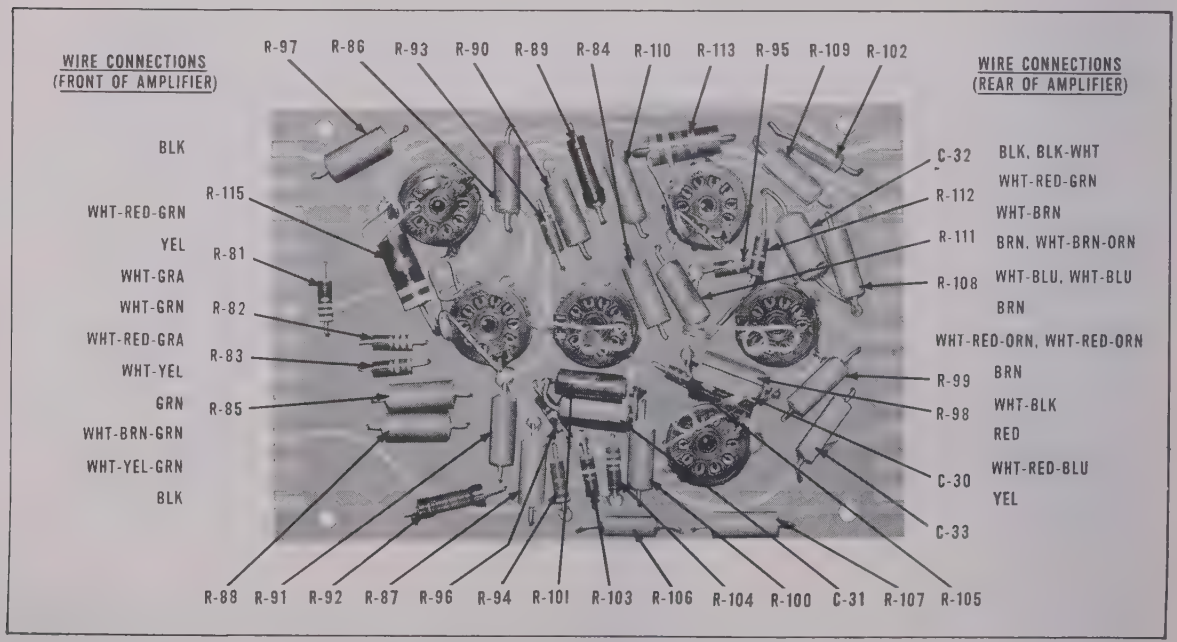


Fig. 37. Printed Wiring Board (Less Tubes).

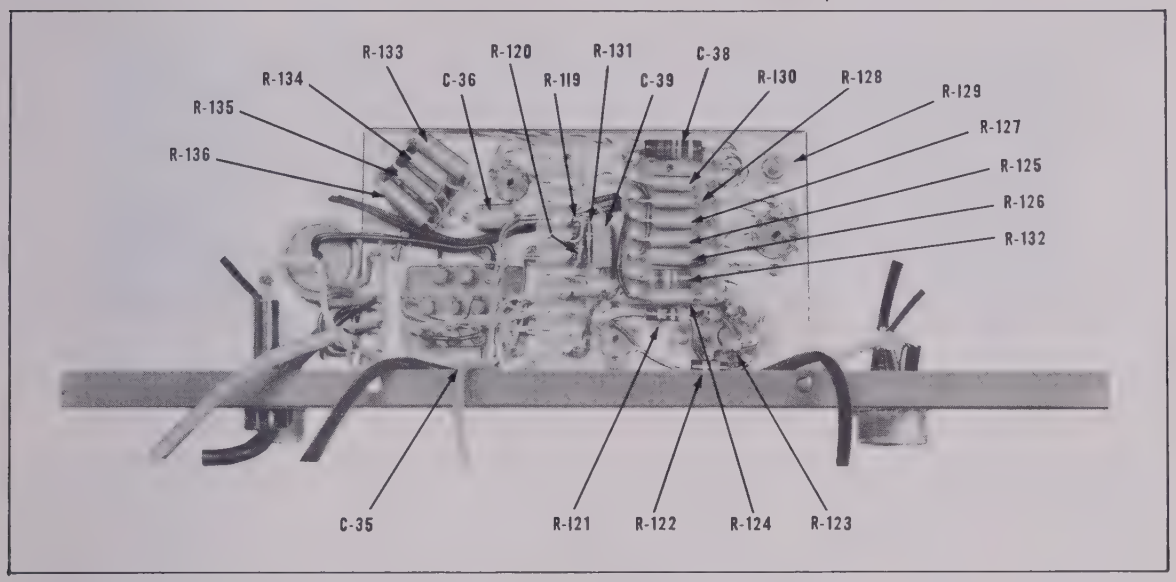


Fig. 38. Top View—Power Supply.

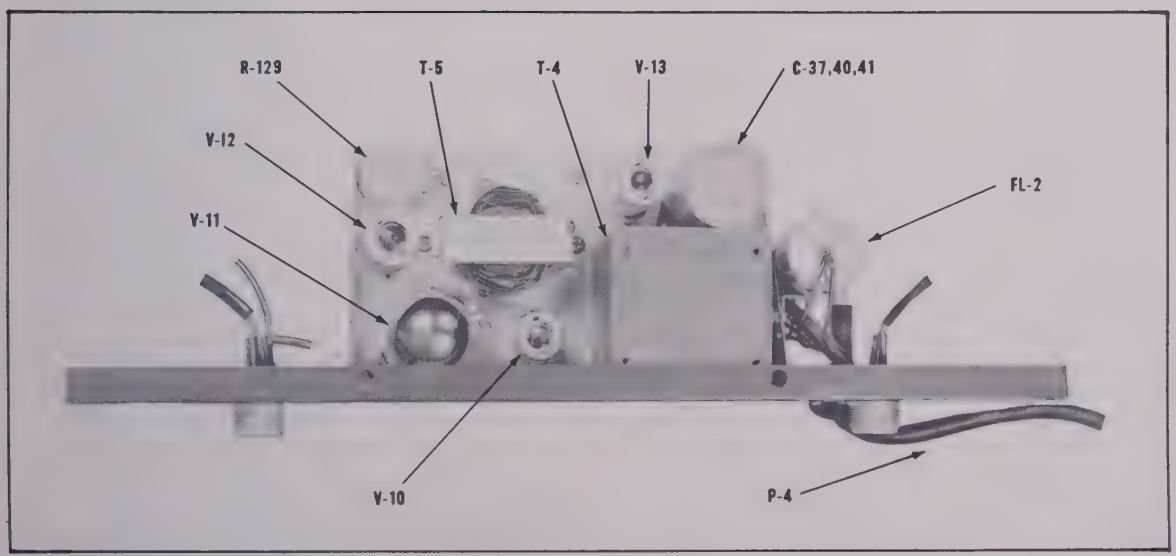


Fig. 39. Bottom View—Power Supply.

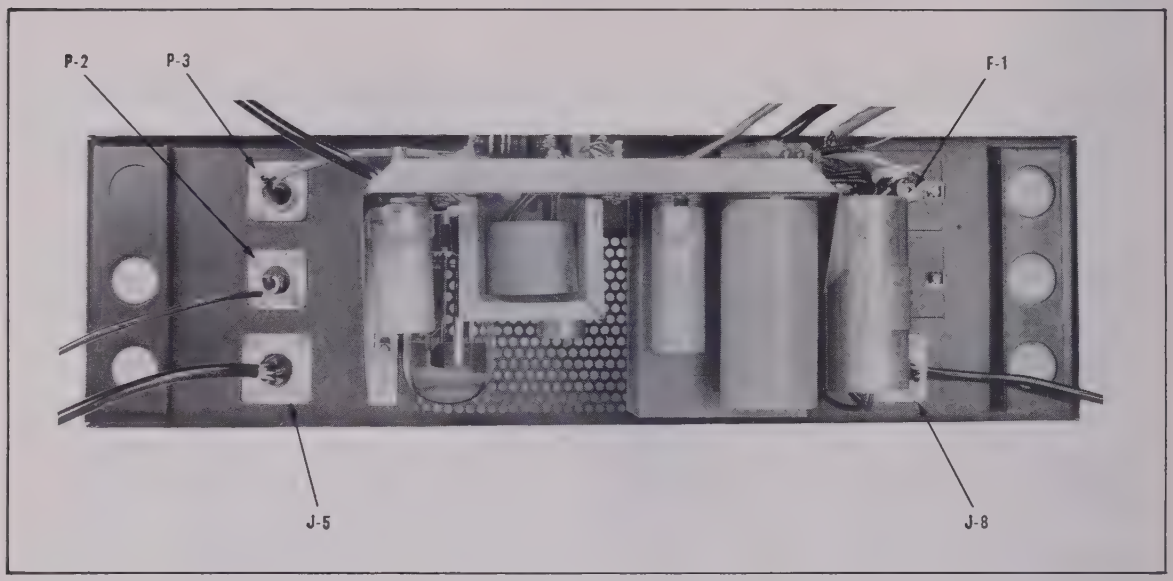


Fig. 40. Inside View—Rear Panel Assembly.

PARTS LIST

In order to assure prompt and satisfactory delivery of replacement parts, it is very necessary that you include the following information with your order:

1. The name and serial number of the instrument for which the parts are to be used. For example, "Universal Amplifier Model RD 5612 00 Serial No. 123".
2. Specific information on desired parts, from the PARTS LIST, as published in the Operating Instructions:
   Description
   Value (Electrical)
   Brush Part No.

NOTE: Do not use the SYMBOL No. for identifying desired parts on your order.

SYMBOL	DESCRIPTION	VALUE	BRUSH PART NO.
B-1	Cell, Mercury	2.5V	126377-4
C-1	Capacitor, Ceramic	.0039 mfd, ± 20%, 500V	20-118102-392
C-2	Capacitor, Mica	.0015 mfd, ± 10%, 500V	10-117265-152
C-3	Capacitor, Paper	0.1 mfd, ± 10%, 200V	10-120554-104
C-4	Capacitor, Mica	330 mmfd, ± 10%, 500V	10-117264-331
C-5	Capacitor, Electrolytic (½ Dual Section)	10 mfd, 450V	117717-106
C-6	Capacitor, Mica	.0047 mfd, ± 5%, 500V	5-122233-472
C-7	Capacitor, Paper	.02 mfd, ±10%, 200V	10-217608-203
C-8	Capacitor, Mica	.01 mfd, ± 5%, 500V	5-122233-103
C-9	Capacitor, Mica	.01 mfd, ± 5%, 500V	5-122233-103
C-10	Capacitor, Mica	.001 mfd, ± 10%, 500V	10-117265-102
C-11	Capacitor, Electrolytic	10 mfd, 25V	100-117680-106
C-12	Capacitor, Electrolytic (½ Dual Section)	10 mfd, 450V	117717-106
C-13	Capacitor, Mica	470 mmfd, ± 10%, 500V	10-117264-471
C-14	Capacitor, Electrolytic (½ Dual Section)	10 mfd, 450V	(Part of C-12)
C-15	Capacitor, Mica	470 mmfd, ± 10%, 500V	10-117264-471
C-16	Capacitor, Electrolytic	10 mfd, 25V	100-117680-106
C-17	Capacitor, Electrolytic (½ Dual Section)	10 mfd, 450V	(Part of C-5)
C-18	Capacitor, Ceramic	.01 mfd, 500V	1-117964-103
C-19	Capacitor, Paper	.5 mfd, ±20%, 200V	20-120554-504
C-20	Capacitor, Ceramic	.002 mfd, 500V	1-117964-202
C-21	Capacitor, Mica	.0033 mfd, ± 10%, 500V	10-117265-332
C-22	Capacitor, Ceramic	510 mmfd, ± 20%, 500V	20-118102-511
C-23	Capacitor, Mica	.001 mfd, ± 10%, 500V	10-117264-102
C-24	Capacitor, Mica	.001 mfd, ± 10%, 500V	10-117264-102
C-25	Capacitor, Mica	270 mmfd, ± 5%, 500V	5-119621-271
C-26	Capacitor, Mica	.0015 mfd, ± 10%, 500V	10-117265-152
C-27	Capacitor, Mica	510 mmfd, ± 5%, 500V	5-117264-511
C-28	Capacitor, Mica	270 mmfd, ± 5%, 500V	5-119621-271
C-29	Capacitor, Paper	.05 mfd, ± 10%, 400V	10-120555-503

PARTS LIST (Cont'd)

SYMBOL	DESCRIPTION	VALUE	BRUSH PART NO.
C-30	Capacitor, Mica	.001 mfd, ± 5%, 500V	5-117264-102
C-31	Capacitor, Mica	.001 mfd, ± 5%, 500V	5-117264-102
C-32	Capacitor, Mylar	.01 mfd, ± 5%, 400V	5-125905-103
C-33	Capacitor, Mica	.001 mfd, ± 5%, 500V	5-117264-102
C-34	Capacitor, Mica	.0024 mfd, ± 5%, 500V	5-122233-242
C-35	Capacitor, Paper	.25 mfd, ± 10%, 200V	10-120554-254
C-36	Capacitor, Paper	.25 mfd, ± 10%, 200V	10-120554-254
C-37	Capacitor, Electrolytic (⅓ Triple Section)	20 mfd, 450V	117718-206
C-38	Capacitor, Paper	.01 mfd, ± 10%, 400V	10-217413-103
C-39	Capacitor, Mica	.0022 mfd, ± 10%, 500V	10-117265-222
C-40	Capacitor, Electrolytic (⅓ Triple Section)	20 mfd, 450V	(Part of C-37)
C-41	Capacitor, Electrolytic (⅓ Triple Section)	20 mfd, 450V	(Part of C-37)
F-1	Fuse	2 Amp, 250V, Type 3AG	102625
FL-1	Filter Assembly		326581-910
FL-2	Filter, Power Line	3 Amp, 110-220V	123361
J-1	Connector, Binding Post (4)	GR Type	126395-3
J-2	Connector, Female	Strip Type	118041-24
J-3	Connector, Binding Post (3)	GR Type	126395-3
J-4	Connector, Female	Strip Type	118041-24
J-5	Connector, Female, 5 Pin	AN Type—AN 3102A-14S-5S	119989
J-6	Connector, Binding Post (2)	GR Type	126395-3
J-7	Connector, Binding Post (3)	GR Type	126395-3
J-8	Connector, Female, 6 Pin	AN Type—AN 3102A-14S-6S	119990
L-1	Coil, Oscillator	1250 mhy	106588-2
NE-1	Lamp, Neon (Red)		126621
P-1	Connector, Male	Strip Type	118040-24
P-2	Connector, Male, 2 Pin	AN Type—AN 3102A-10SL-4P	119972
P-3	Connector, Male, 3 Pin	AN Type—AN 3102A-10SL-3P	121274
P-4	Plug, Power, With Cord	2 Conductor	126551-6
R-1	Resistor, Precision (Calibration)	390K, ± 1%, ½ W	109577-3903
R-2	Resistor, Variable, 10 Turn	2K, 1½W	119048
R-3	Resistor, Variable, 10 Turn	2K, 1½W	119048
R-4	Resistor, Composition	240K, ± 5%, ½W	5-115557-244
R-5	Resistor, Composition	56K, ± 5%, ½W	5-115557-563
R-6	Resistor, Composition	24K, ± 5%, ½W	5-115557-243
R-7	Resistor, Composition	4.7K, ± 5%, ½W	5-115557-472
R-8	Resistor, Composition	1.5K, ± 5%, ½W	5-115557-152
R-9	Resistor, Variable, 10 Turn	2K, 1½W	119048
R-10	Resistor, Precision	150K, ± 1%, ½W	1-117802-1503
R-11	Resistor, Precision	220 ohms, ± 1%, ½W	1-117802-2200
R-12	Resistor, Composition	20 ohms, ± 5%, ½W	5-115557-200
R-13	Resistor, Variable, 10 Turn	2K, 1½W	119048
R-14	Resistor, Composition	10K, ± 5%, 1W	5-115558-103
R-15	Resistor, Precision	150K, ± 1%, ½W	1-117802-1503
R-16	Resistor, Variable	100K	19-211473-104
R-17	Resistor, Precision	245K, ± 1%, ½W	1-117802-2453
R-18	Resistor, Precision	154K, ± 1%, ½W	1-117802-1543
R-19	Resistor, Precision	51.0K, ± 1%, ½W	1-117802-5102
R-20	Resistor, Precision	25.0K, ± 1%, ½W	1-117802-2502
R-21	Resistor, Precision	15.0K, ± 1%, ½W	1-117802-1502
R-22	Resistor, Precision	5.00K, ± 1%, ½W	1-117802-5001
R-23	Resistor, Precision	2.50K, ± 1%, ½W	1-117802-2501
R-24	Resistor, Precision	1.50K, ± 1%, ½W	1-117802-1501
R-25	Resistor, Precision	5.00K, ± 1%, ½W	1-117802-5000
R-26	Resistor, Precision	5.00K, ± 1%, ½W	1-117802-5000

PARTS LIST (Cont'd)

SYMBOL	DESCRIPTION	VALUE	BRUSH PART NO.
R-27	Resistor, Precision	4.7K, ± 1%, ½W	1-117802-4701
R-28	Resistor, Precision	1.0M, ± 1%, ½W	1-117802-1004
R-29	Resistor, Composition	270K, ± 5%, ½W	5-115557-274
R-30	Resistor, Composition	1.0M, ± 5%, ½W	5-115557-105
R-31	Resistor, Composition	8.2K, ± 5% ½W	5-115557-822
R-32	Resistor, Composition	270K, ± 5%, ½W	5-115557-274
R-33	Resistor, Composition	82K, ± 5%, ½W	5-115557-823
R-34	Resistor, Variable	1.0M	10-212023-105
R-35	Resistor, Composition	1.0K, ± 5%, ½W	5-115557-102
R-36	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-37	Resistor, Composition	1.0M, ± 5%, ½W	5-115557-105
R-38	Resistor, Precision	117K, ± 1%, ½W	1-117802-1173
R-39	Resistor, Composition	47K, ± 5%, ½W	5-115557-473
R-40	Resistor, Composition	680 ohms, ± 5%, ½W	5-115557-681
R-41	Resistor, Composition	10K, ± 5%, 1W	5-115558-103
R-42	Resistor, Composition	22K, ± 5%, ½W	5-115557-223
R-43	Resistor, Composition	22K, ± 5%, ½W	5-115557-223
R-44	Resistor, Precision	1.0M, ± 1%, ½W	1-117802-1004
R-45	Resistor, Variable	250K	19-211473-254
R-46	Resistor, Precision	1.0M, ± 1%, ½W	1-117802-1004
R-47	Resistor, Precision	1.0M, ± 1%, ½W	1-117802-1004
R-48	Resistor, Precision	330K, ± 1%, ½W	1-117802-3303
R-49	Resistor, Precision	330K, ± 1%, ½W	1-117802-3303
R-50	Resistor, Precision	165K, ± 1%, ½W	1-117802-1653
R-51	Resistor, Composition	220K, ± 5%, ½W	5-115557-224
R-52	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-53	Resistor, Composition	10K, ± 5%, ½W	5-115557-103
R-54	Resistor, Composition	27K, ± 5%, ½W	5-115557-273
R-55	Resistor, Composition	270K, ± 5%, ½W	5-115557-274
R-56	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-57	Resistor, Precision	2.50M, ± 0.5%, ½W	50-117802-2504
R-58	Resistor, Precision	1.25M, ± 0.5%, ½W	50-117802-1254
R-59	Resistor, Precision	750K, ± 0.5%, ½W	50-117802-7503
R-60	Resistor, Precision	250K, ± 0.5%, ½W	50-117802-2503
R-61	Resistor, Precision	125K, ± 0.5%, ½W	50-117802-1253
R-62	Resistor, Precision	75.0K, ± 0.5%, ½W	50-117802-7502
R-63	Resistor, Precision	25.0K, ± 0.5%, ½W	50-117802-2502
R-64	Resistor, Precision	25.0K, ± 0.5%, ½W	50-117802-2502
R-65	Resistor, Precision	.95M, ± 1%, ½W	1-117802-9503
R-66	Resistor, Precision	.56M, ± 1%, ½W	1-117802-5603
R-67	Resistor, Precision	2.50M, ± 0.5%, ½W	50-117802-2504
R-68	Resistor, Precision	1.25M, ± 0.5%, ½W	50-117802-1254
R-69	Resistor, Precision	750K, ± 0.5%, ½W	50-117802-7503
R-70	Resistor, Precision	250K, ± 0.5%, ½W	50-117802-2503
R-71	Resistor, Precision	125K, ± 0.5%, ½W	50-117802-1253
R-72	Resistor, Precision	75.0K, ± 0.5%, ½W	50-117802-7502
R-73	Resistor, Precision	25.0K, ± 0.5% ½W	50-117802-2502
R-74	Resistor, Precision	25.0K, ± 0.5%, ½W	50-117802-2502
R-75	Resistor, Composition	15K, ± 5%, ½W	5-115557-153
R-76	Resistor, Variable	1.0M	2-212022-105
R-77	Resistor, Composition	470K, ± 5%, ½W	5-115557-474
R-78	Resistor, Variable, 10 Turn	50K, 4W	5-117686-503
R-79	Resistor, Variable	10K	19-211473-103
R-80	Resistor, Variable	3K, ± 20%, ½W	20-125156-302
R-81	Resistor, Composition	33K, ± 5%, ½W	5-115557-333

PARTS LIST (Cont'd)

SYMBOL	DESCRIPTION	VALUE	BRUSH PART NO.
R-82	Resistor, Composition	33K, ± 5%, ½W	5-115557-333
R-83	Resistor, Composition	12K, ± 5%, ½W	5-115557-123
R-84	Resistor, Precision	250K, ± 1%, ½W	1-117802-2503
R-85	Resistor, Precision	250K, ± 1%, ½W	1-117802-2503
R-86	Resistor, Precision	2.50M, ± 1%, ½W	1-117802-2504
R-87	Resistor, Precision	350K, ± 1%, ½W	1-117802-3503
R-88	Resistor, Precision	2.50M, ± 1%, ½W	1-117802-2504
R-89	Resistor, Precision	4.00M, ± 1%, ½W	1-117802-4004
R-90	Resistor, Precision	2.50M, ± 1%, ½W	1-117802-2504
R-91	Resistor, Precision	2.50M, ± 1%, ½W	1-117802-2504
R-92	Resistor, Precision	4.00M, ± 1%, ½W	1-117802-4004
R-93	Resistor, Composition	3.6K, ± 5%, ½W	5-115557-362
R-94	Resistor, Composition	3.6K, ± 5%, ½W	5-115557-362
R-95	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-96	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-97	Resistor, Precision	39.0K, ± 1%, ½W	1-117802-3902
R-98	Resistor, Precision	1.10M, ± 1%, ½W	1-117802-1104
R-99	Resistor, Precision	390K, ± 1%, ½W	1-117802-3903
R-100	Resistor, Precision	390K, ± 1%, ½W	1-117802-3903
R-101	Resistor, Precision	1.10M, ± 1%, ½W	1-117802-1104
R-102	Resistor, Precision	3.30M, ± 1%, ½W	1-117802-3304
R-103	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-104	Resistor, Precision	27.0K, ± 1%, ½W	1-117802-2702
R-105	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-106	Resistor, Precision	3.30M, ± 1%, ½W	1-117802-3304
R-107	Resistor, Precision	1.00M, ± 1%, ½W	1-117802-1004
R-108	Resistor, Precision	1.72M, ± 1%, ½W	1-117802-1724
R-109	Resistor, Precision	470K, ± 1%, ½W	1-117802-4703
R-110	Resistor, Precision	470K, ± 1%, ½W	1-117802-4703
R-111	Resistor, Precision	1.72M, ± 1%, ½W	1-117802-1724
R-112	Resistor, Composition	15K, ± 5%, ½W	5-115557-153
R-113	Resistor, Composition	1.1K, ± 5%, 2W	5-115559-112
R-114	Resistor, Ballast		126577
R-115	Resistor, Composition	43 ohms, ± 5%, 2W	5-115559-430
R-116	Resistor, Variable (½ Dual Section)	1.0M, ± 5%, ½W	126255
R-117	Resistor, Variable (½ Dual Section)	1.0M, ± 5%, ½W	(Part of R-116)
R-118	Resistor, Precision	1.00M, ± 1%, ½W	1-117802-1004
R-119	Resistor, Composition	330K, ± 5%, ½W	5-115557-334
R-120	Resistor, Composition	220K, ± 5%, ½W	5-115557-224
R-121	Resistor, Composition	68 ohms, ± 5%, 1W	5-115558-680
R-122	Resistor, Composition	68 ohms, ± 5%, 1W	5-115558-680
R-123	Resistor, Composition	100 ohms, ± 5%, ½W	5-115557-101
R-124	Resistor, Precision	1.00M, ± 1%, ½W	1-117802-1004
R-125	Resistor, Precision	5.00M, ± 1%, ½W	1-117802-5004
R-126	Resistor, Precision	5.00M, ± 1%, ½W	1-117802-5004
R-127	Resistor, Precision	1.00M, ± 1%, ½W	1-117802-1004
R-128	Resistor, Precision	350K, ± 1%, ½W	1-117802-3503
R-129	Resistor, Variable	100K	19-211473-104
R-130	Resistor, Precision	150K, ± 1%, ½W	1-117802-1503
R-131	Resistor, Composition	220K, ± 5%, ½W	5-115557-224
R-132	Resistor, Composition	10K, ± 5%, 2W	5-115559-103
R-133	Resistor, Precision	27.0K, ± 1%, 1W	1-117803-2702
R-134	Resistor, Precision	2.20K, ± 1%, ½W	1-117802-2201
R-135	Resistor, Precision	2.20K, ± 1%, ½W	1-117802-2201
R-136	Resistor, Precision	18.0K, ± 1%, 1W	1-117803-1802

PARTS LIST (Cont'd)

SYMBOL	DESCRIPTION	VALUE	BRUSH PART NO.
S-1	Switch, Toggle, D.P.D.T., Momentary Contact		124334
S-2	Switch, Toggle, S.P.S.T.		1-103258-201
S-3	Switch, Rotary		127540
S-4	Switch, Toggle, S.P.S.T.		1-103258-201
S-5	Switch, Rotary		226513
S-6	Switch, Rotary		126453
S-7	Switch, Rotary		226394
S-8	Switch, Rotary		226427
S-9	Switch, D.P.S.T.		(Part of R-116)
S-10	Switch, Toggle, S.P.S.T.		121068
T-1	Transformer		120141
T-2	Transformer		106602-1
T-3	Transformer		118535
T-4	Transformer		121553
T-5	Transformer		118920
V-1	Tube, Electron, 12AU7		125834
V-2	Tube, Electron, 12AX7		125835
V-3	Tube, Electron, 12AT7WA		125833
V-4	Tube, Electron, 6AL5		109996
V-5	Tube, Electron, 12AX7		125835
V-6	Tube, Electron, 12AT7WA		125833
V-7	Tube, Electron, 12AT7WA		125833
V-8	Tube, Electron, 5687		122828
V-9	Tube, Electron, 5687		122828
V-10	Tube, Electron, 6BW4		126997
V-11	Tube, Electron, 6080		115687
V-12	Tube, Electron, 5751		119028
V-13	Tube, Electron, 6626		107098
WB-1	Board, Printed Wiring (Less Tubes)		326545-910

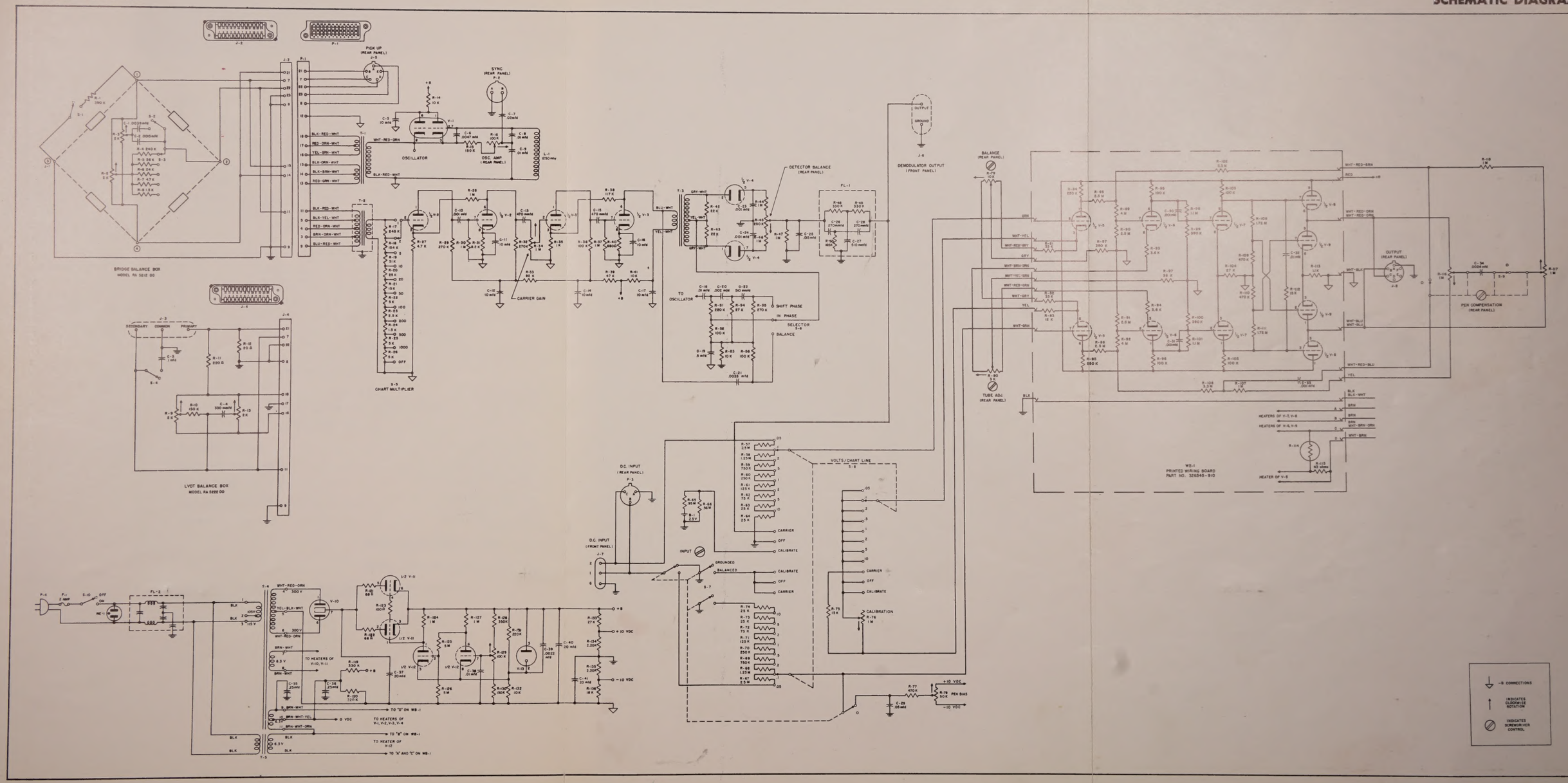
TUBE SOCKET PIN VOLTAGES

1. Voltages should be measured under the following conditions:
   a. VOLTS/CHART LINE switch set in the "off" position.
   b. CALIBRATION control fully counterclockwise.
   c. A 1500 ohm resistor connected across the output terminals (pins "B" and "C" of the output connector).
   d. Voltage across the output resistor adjusted to zero (0 volts) by means of the PEN BIAS control.
   e. CHART MULTIPLIER switch set in the "off" position.
   f. CARRIER GAIN control fully counterclockwise.
   g. SELECTOR switch in the "balance" position.
2. All d.c. measurements should be made with a d.c. voltmeter with a minimum of ten (10) megohms input impedance.
3. All a.c. voltages should be measured with an accurate RMS a.c. voltmeter (20,000 ohms per volt or higher).
4. The +B voltage should be adjusted to 235 volts as described in the Operating Instructions under "Tube Replacement" (Section V—Maintenance).
5. All measurements should be made from the tube pin to −B (⏚) point, except where otherwise noted.
6. Variations in observed voltage readings from tabulated values do not necessarily indicate improper operation unless deviations exceed 10%.

TUBE No.	TYPE	PIN NUMBER								
		1	2	3	4	5	6	7	8	9
V-1	12AU7	170	0	7	Note 1		170	0	7	—
V-2	12AX7	90	0	1.0	Note 1		79	0	1.0	—
V-3	12AT7WA	107	0	2.0	Note 1		174	0	2.0	—
V-4	6AL5	97	97	Note 2		120	—	74	—	—
V-5	12AX7	197	97	98	Note 1		197	97	98	—
V-6	12AT7WA	155	56	57	Note 1		155	56	57	—
V-7	12AT7WA	152	41	42	Note 1		152	41	42	—
V-8	5687	235	150	154	Note 3		154	150	—	235
V-9	5687	153	33	37	Note 3		137	33	—	153
V-10	6BW4	—	305	Note 2		—	—	305	—	—
V-11	6080	200	302	235	200	302	235	Note 4		—
V-12	5751	200	87	86	Note 1		182	87	86	—
V-13	0A2	—	87	—	—	235	—	—	—	—

NOTES:

1. 6.3 volts a.c. measured from pins 4 and 5 to pin 9.
2. 6.3 volts a.c. measured from pin 3 to pin 4.
3. 6.3 volts a.c. measured from pins 4 and 5 to pin 8.
4. 6.3 volts a.c. measured from pin 7 to pin 8.

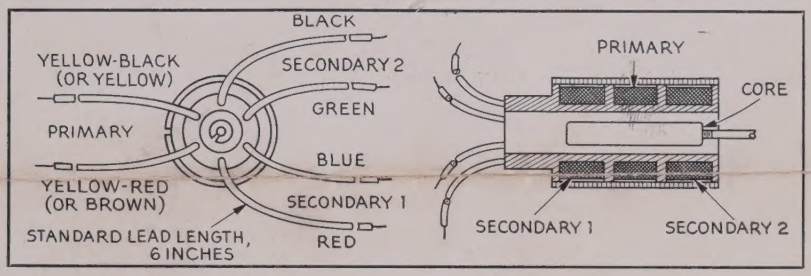

BRIDGE BALANCE BOX
MODEL RA 5612 00
LVDT BALANCE BOX
MODEL RA 5222 00
PICK UP
(REAR PANEL)
SYNC
(REAR PANEL)
OSCILLATOR
OSC. AMP
(REAR PANEL)
CHART MULTIPLIER
CARRIER GAIN
DETECTOR BALANCE
(REAR PANEL)
DEMODULATOR OUTPUT
(FRONT PANEL)
SHIFT PHASE
IN PHASE
SELECTOR
BALANCE
D.C. INPUT
(REAR PANEL)
D.C. INPUT
(FRONT PANEL)
INPUT
GROUNDED
BALANCED
CALIBRATE
OFF
CARRIER
VOLTS/CHART LINE
CALIBRATION
BALANCE
(REAR PANEL)
TUBE ADJ.
(REAR PANEL)
OUTPUT
(REAR PANEL)
PEN COMPENSATION
(REAR PANEL)
PEN BIAS
+10 VDC
-10 VDC
0 VDC
WB-1
PRINTED WIRING BOARD
PART NO. 326545-510
HEATERS OF V-1, V-8
HEATERS OF V-5, V-9
HEATER OF V-6
-B CONNECTIONS
INDICATES CLOCKWISE ROTATION
INDICATES SCREWDRIVER CONTROL

schaevitz engineering

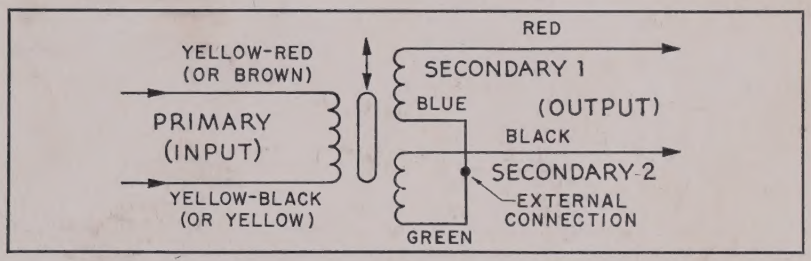
P. O. Box 505
Camden 1, New Jersey
Phone: MErchantville 8-5353
TWX — MERCHANTVILLE N J 386

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER

Type 250 S-CT Serial No. 837



Standard colored lead terminations showing relative positions of windings.



Schematic representation of the LVDT

TEST DATA

S-3

☐ as specified on Purchase Order

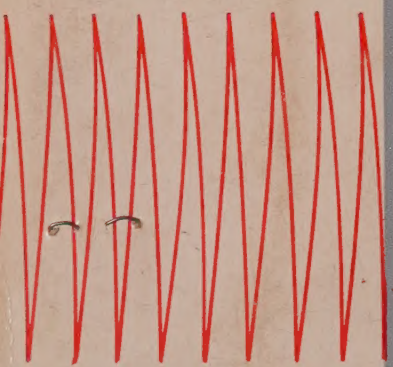
☑ standard test

Excitation voltage	6	volts
Excitation frequency	60	cps
Linear range	± .250	inches
Null (balance point)	6.8	millivolts
Output	1.150 .5 m. com	volts

Tested by L R Bennett

Date 12-20-57

Refer to "Notes on Linear Variable Differential Transformers" for details on operating data.



BRUSH ELECTRONICS COMPANY
DIVISION OF CLEVITE CORPORATION
3405 Perkins Avenue • Cleveland 14, Ohio

MP MASTER
MA30149